

Water Sensitive Urban Design as a Transformative Approach to
Urban Water Management in Cape Town: A Case Study of the
Proposed River Club Development



School of Architecture, Planning and Geomatics

University of Cape Town

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November 2017

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Water Sensitive Urban Design as a Transformative Approach to Urban Water Management in Cape Town: A Case Study of the Proposed River Club Development

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A minor dissertation submitted in partial fulfillment of the requirements for
the award of the degree of Masters in City and Regional Planning

Faculty of Engineering and the Built Environment

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November 2017

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Abstract:

The author examines effective urban water management as a means to promote sustainable development and achieve water sensitive cities. A qualitative method is utilised in the collection of data through document studies, desktop analysis and a literature review. A review of the current national and local water policies and approaches within South Africa, and more specifically Cape Town, indicated the need for a coordinated, systems based and holistic approach to urban water management. Water Sensitive Urban Design (WSUD) is considered as an alternative approach to urban water management in Cape Town to build resilience among local communities against the threat of drought and flood events, and promote sustainable development in moving toward a water sensitive city. A model for implementing WSUD in the context of limited resources and capacity within local municipal departments is considered. Incorporating the principles of WSUD within spatial planning initiatives to implement this approach and catalyse a systemic transition in urban water management is considered and assessed in a case study of the proposed development of the River Club. The case study considers a bottom-up approach to transforming urban water management and the capacity of WSUD, when implemented through spatial planning, to simultaneously address multiple objectives including those of sustainable development and those contained within national and local policies. The benefits of a WSUD approach for all are considered. Many if these benefits are as a result of reduced pressures on municipal infrastructure and increased water resources accrued as a product of the proposed implementation model. The implementation model proposed creates conditions in which municipal resources and investment can be redirected to promote equitable water resource and service provision distribution throughout the city. The model is proposed to effect a transformation in water policy, institutional structures and water resource management to reflect the principles of WSUD in a manner which is cognisant of the various limitations inherent to the City.

Key Words: Water Sensitive Urban Design, Spatial Planning, Sustainable Development, Resilience, Urban

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List of Acronyms:

BMPs – Best Management Practices

BPPs – Best Planning Practices

CBAs – Critical Biodiversity Areas

CMAs – Catchment Management Areas

Co₂ – Carbon Dioxide

CoCT – City of Cape Town

DWA – Department of Water Affairs

ESSs – Ecosystem Services

FRCMP - Floodplain and River Corridor Management Policy

GHG – Greenhouse Gas

IDP – Integrated Development Plan

LCA – Life Cycle Assessment

MFA – Material Flow Analysis

mm – Millimeters

NDP – National Development Plan

NEMA - National Environmental Management Act

NFEPAs - National Freshwater Ecosystem Priority Areas

NPC – National Planning Commission

NWA – National Water Act

NWP – National Water Policy

NWRS - National Water Resource Strategy

NWRS 2 - National Water Resource Strategy 2

pa – per annum

PSDF – Provincial Spatial Development Framework

RSA – Republic of South Africa

SDF – Spatial Development Framework

SDP – Spatial Development Plan

SOE – State of the Environment

SuDS – Sustainable Urban Drainage Systems

SUWM – Sustainable Urban Water Management

UN – United Nations

WCED – World Commission on Environment and Development

WCG – Western Cape Government

WCWDMS - Water Conservation and Water Demand Management Strategy

WHO -World Health Organisation

WSDP – Water Services Development Plans

WSUD – Water Sensitive Urban Design

WWT – Waste Water Treatment

WWTW – Waste Water Treatment Works

Useful Definitions:

City:	An area characterised by dense human settlement, spatially concentrated economic, social and environmental interactions and an agglomeration of infrastructure including communication, service provision and housing systems.
Climate Change:	Long-term, persistent change in local and/or global climatic conditions and patterns largely as a result of human activities.
Community Resilience:	The capacity of local communities to mobilise resources in a manner which reduces the negative impacts of adverse events such as drought and flooding.
Equality:	A fair and equal state in which all have access to the same opportunities and rights.
Ecosystem Services:	“ecosystem goods and services are the benefits that humans derive (directly and indirectly) from naturally functioning ecological systems”(Costanza et al 1997:4).
Groundwater:	Any, and all water resources below ground level.
Hydrologic (Water) Cycle:	“A conceptual model describing the storage and circulation of water between the biosphere, atmosphere, lithosphere, and the hydrosphere”(Marsalek <i>et al</i> , 2008:2).
Interdisciplinarity:	The combining of two or more fields of knowledge in a collaborative manner in achieving a defined objective.
Public Participation:	An approach to problem solving which facilitates the collaboration of members of the public, various originations and other stakeholders in the decision making process.
Spatial Planning:	“Spatial planning gives geographical expression to the economic, social, cultural and ecological policies of society. It is at the same time a scientific discipline, an administrative technique and a policy developed as an interdisciplinary and comprehensive approach directed towards a balanced regional development and the physical organisation of space according to an overall strategy”(Nilsson & Ryden, 2012:205)
Stakeholder:	Any interested or affected parties
Stormwater runoff:	Ground surface flows of water accumulated during rainfall events.
Sustainable Development:	“Development which meets the needs of the present without compromising the ability of future generations to meet their own needs”(WCED, 1987:43) This definition is elaborated upon in the context of this dissertation: Development which promotes equitable economic and social growth and development in an manner which does not jeopardise the integrity and functioning of the natural environment.

Sustainable City:	A city which is designed to minimise required inputs (energy and resources) and outputs (waste) in the promotion of economic and social development which protects the natural environment.
Transitions:	“Societal processes of fundamental change in culture, structure and practices”(Nevens <i>et al</i> , 2013:112)
Urban Design:	A discipline “concerned with the physical form of the public realm over a limited physical area of the city [] concerned with the physical form of the private realm of the individual building, and (the objectives of) town and regional planning”(Bahrainy & Bakhtiar ,2016:6)
Urbanisation:	A phenomenon involving the migration of people residing in rural areas to urban areas resulting in increases in urban populations.
Urban Metabolism:	“The sum total of the technical and socio-economic processes that occur in cities resulting in growth, production of energy, and elimination of waste”(Kennedy <i>et al</i> , 2011:1).
Urban Water Metabolism:	A means to holistically describe and analyse the flow of water resources through an urban system.
Water Sensitive City:	A city which enhances water security, protects the natural environment and natural urban water bodies, enhances provision of ecosystem services, builds resilience among local communities against drought and flood events and addresses numerous additional economic, social and environmental objectives through a well devised approach to urban water management.

Note:

City: (Proper Noun) Describes the City of Cape Town (local government)

city: (Noun) Describes the city as a place

Chapter 1: Introduction

Introduction

Urbanisation and the rapid growth of cities have placed unprecedented strains on Earth's natural resources. Climate change and rapid population growth have exacerbated these strains reducing the resilience of communities around the world. Urbanisation and population growth are most rapid in developing countries within Asia and Sub-Saharan Africa, which are areas generally characterised by resource inefficiencies and where local governments do not possess the necessary financial and institutional capacity to adapt appropriately (Buhaug & Urdal, 2013). Shifts in global climatic conditions and increasing frequency of extreme weather events such as drought and flooding is hard felt within these countries where resource deficiencies reduce their ability to respond to, and build resilience against, such events (Buhaug & Urdal, 2013). In addition, the rapid rate of urban population growth has placed significant pressures on the ability of local governments to meet societal demands for housing and service provision (Buhaug & Urdal, 2013). The growth of cities also places significant pressures on the natural environment as increased demand drives more intensive measures to harvest natural resources resulting in resource depletion perpetuated by the associated reductions in the productive capacity of the natural environment. The urban form itself has implications for local and global environmental conditions, for example hydrological functioning is altered through the modification of natural drainage systems and local climatic conditions are altered as a result of the urban heat island effect (Rizwan *et al*, 2008).

Interest in sustainable development, defined as, "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development (WCED), 1987:43), has grown internationally in enhancing the sustainability of cities. Sustainable cities, through sustainable development, endeavour to achieve a balance between economic and social development and the protection of the natural environment. Desires for sustainable development have driven global shifts in urban water management strategies to adjust to changing global climatic conditions and population growth. Strategies to enhance urban water management are targeted toward the achievement of a water sensitive city. Such a city should be characterised by resilience among communities against the adverse effects of natural disasters, the protection and sustainable use of the natural environment and its associated resources, sustainable economic growth and development, and enhanced liveability, equality, human health and well-being (Brown *et al*, 2007).

Infrastructure plays a fundamental role in the promotion of sustainable development and water sensitive cities. Infrastructure maintains the capacity to promote economic growth and development,

enhance social conditions through service delivery and promote the protection of the natural environment (Jordan & Infante, 2012). Water sensitive cities can be achieved through the development of appropriate infrastructure designed to address issues inherent to a specific city. Urban water management relies heavily on adequate infrastructure in delivering services including water supply and sanitation and creating more efficient management strategies. The capacity of infrastructure to manipulate the urban water metabolism in reducing input requirements and waste production relies upon the effectiveness of management strategies in selecting and designing appropriate infrastructural systems to support the manipulation of the urban hydrological cycle (Newell & Cousins, 2015). The manipulation of this cycle in achieving a water sensitive city must be conducted in a manner which reflects economic, social and environmental sustainability.

The current capacity of numerous cities, particularly those within developing countries, to respond adequately to climate change and population growth is exacerbated by infrastructure inadequacies and insufficient institutional resources and arrangements (Wong & Brown, 2009). Cities within the global south are often characterised by limited financial resources, a lack of institutional capacity and insufficient legislation and policy (Watson, 2014). Furthermore, these cities often experience service delivery deficits as a result of insufficient infrastructure and infrastructure failure directing already limited resources toward addressing infrastructural upgrading, maintenance and repair. This drastically reduces the capacity of these cities to bring about systemic change in urban water management and achieve a water sensitive state.

Cape Town, South Africa is currently facing a water crisis as a result of a prolonged period of drought requiring the city to rethink its approach to water management. The city relies on rainfall during the winter months, April to September, to supply water to dams which are relied upon by the city for water supply (SRK, 2017). Current estimates predict that, due reductions in winter rainfall, these dams will no longer possess the capacity to supply water resources to Cape Town by as early as March 2018 (Haden, 2017). Data indicates consistent reductions in winter rainfall in the catchments to the east of Cape Town responsible for the city's water supply since 2014 (Haden, 2017). Research, as early as 2003, indicated that Cape Town lacked sufficient water resources to adapt to increases in demand through population growth and reductions in supply as a result of climate change with the first National Water Resource Strategy (NWRS) (Department of Water Affairs (DWA), 2004) noting that, "Water requirements in the greater Cape Town sub-area are already well in excess of water availability"(DWA, 2004:D19.4). Water resource deficits have major implications for future economic growth and development, social factors such as human health and well-being, and a vast array of environmental consequences.

The water crisis currently faced by Cape Town, arguably, could have been avoided by appropriate transformations in water management approaches in response to data contained within the NWRS in 2003 indicating imminent water resource deficits. The City of Cape Town (CoCT) is now faced with the dilemma of transforming urban water management over a short time frame to avoid catastrophic outcomes. The response of the City will require an approach to urban water management which promotes sustainability and builds resilience among local communities. Questions have been raised as to the ability of the City to adequately adapt to these environmental stressors and transform management approaches given its status as a developing city and the limited financial resources and capacity within governmental institutions which is a common characteristic of these cities. The transformation of Cape Town's approach to water management will require the collaboration of professionals and stakeholders from a multitude of backgrounds in an interdisciplinarity manner.

This dissertation aims to review water resource management within South Africa and, more specifically, Cape Town to identify some of the major water management challenges currently faced by the city and investigate the capacity of the City to respond to the current water crisis in adapting its water management strategy. Water Sensitive Urban Design (WSUD), a water management approach which has emerged in Australia, is considered as a possible alternative approach to water management within Cape Town. It is reviewed in terms of its capacity to reduce pressures on municipal resources and infrastructure and its ability to promote a water sensitive city through sustainable development.

WSUD has exhibited great success within a number of cities of the global north however its application and implementation within cities of the global south can be expected to differ given the comparative limited capacity of these cities. The role of spatial planning is thus explored as a potential mechanism through which to promote the implementation of WSUD and catalyse a systemic change in Cape Town's urban water management. The report aims to further explore this idea and the relationship between WSUD and spatial planning by means of a case study of the proposed development of the River Club as a means to enable systemic change.

Philosophical and Ethical Position

I believe that urban environments should be planned to ensure equal opportunities and access to all regardless of race, religion, gender and, income level. I believe in sustainable development solutions to achieve economic and social growth and development whilst not jeopardising the integrity of the natural environment and in a manner which facilitates the ability to meet present needs without impacting upon the prosperity of future generations.. The racial transgressions accrued during Apartheid remain evident throughout South African cities. Cape Town is no exception as spatial divide and the inequitable distribution of services, resources, opportunities and infrastructure remain

characteristics of the city today. I believe that sustainable development should be integrated within spatial planning initiatives to address these issues within a sustainable development framework. As rates of urbanisation and human population growth continue their upward trend and climate change continues to present major threats to communities all over the globe, I believe that urban areas should direct resources toward building resilience within local communities, especially the urban poor, so as to provide all with an opportunity to enhance their socio-economic position to improve health and well-being.

I regard innovation and collaboration as key enablers to achieving multiple objectives in creating equitable, resilient and sustainable urban environments. In developing countries the onus should not rest solely upon government to enhance urban environments in such a manner. I believe that in the context of limited resources and the inequitable distribution of wealth that often plagues developing cities all should have a role to play in improving these areas for the betterment of all. This includes the involvement of members of the public, private sector, public sector and all stakeholders and other interested parties. I believe that spatial planning and urban design have a major role to play in facilitating such a movement by promoting public participation and interdisciplinarity in implementing and catalysing change which reflects the above mentioned ideals.

Cape Town is currently in a position where change is required to promote a higher standard of living for all within the city by increasing resilience through various transformations in urban management approaches. I believe that economic, social and environmental factors and considerations should be incorporated within management approaches to reflect a holistic approach and promote sustainable outcomes. System-based approaches to the management of urban systems should be adopted and considered within spatial planning so as to facilitate the achievement of multiple economic, social and environmental objectives within the city including densification, enhanced connectivity, equality, improved 'sense of place', environmental protection, economic growth and development and, inclusive developments. The current water crisis in Cape Town I believe necessitates a transformation in urban water resource management. I believe that a holistic, systems-based, approach should be adopted for the management of the urban water cycle as I believe that, through the incorporation of this form of management within spatial planning, multiple city-wide objectives can be addressed simultaneously in a coordinated manner.

[Justification for this Research](#)

The unprecedented water crisis within Cape Town has some projections predicting complete water resource depletion as early as March 2018 (Haden, 2017). Some maintain that this crisis could have been avoided had the City adapted and innovated its approach to urban water management, in

accordance with the information of declining trends in annual precipitation as indicated by the NWRS. Local government is currently faced with the task of generating solutions to overcome this water crisis whilst contending with multiple urban economic, social and environmental objectives. Valuable resources required to address these numerous objectives are currently being redirected toward infrastructural solutions such as desalination plants. These infrastructural solutions are, I believe, short-sighted as numerous water-related infrastructural systems throughout Cape Town are currently operating over capacity this, coupled with ageing, failing and insufficient systems to meet the demands of a growing urban population, will render solutions like desalinisation plants obsolete.

I believe that Cape Town requires an innovative alternative solution to urban water management. As such I aim to explore the scope of WSUD as an alternative management approach which will provide an opportunity for Cape Town to transform urban water management in a manner which builds resilience within local communities and simultaneously addresses the multiple economic, social and environmental factors in so doing promoting sustainable development. Furthermore, I aim to consider the role of spatial planning within this alternative approach and innovative ways through which to implement WSUD under the city's current socio-political and socio-economic conditions.

Aim of Study

Cape Town currently faces severe water shortages with some estimates predicating total system failure by as early as March 2018 (Haden, 2017). Predictions from as early as 2003 projected future water deficits largely as a result of a growing urban population and climate change (DWA, 2003). The failure of the CoCT to respond to these projections by transforming its approach to urban water management has exacerbated the current crisis. The City is now under pressure to transform this approach in a short time frame, incurring extensive financial costs. This study aims to address this problem by reviewing the current urban water management approach of Cape Town in order to decipher the capability of the City to bring about such a transformation. This dissertation aims to address this problem by providing an alternative urban water management approach and exploring an alternative means through which to catalyse a systemic transition. The following research questions and objectives guide this research.

Research Questions

1. What are the national and local legislation, policy, institutional and management structures currently responsible for water resource management in South Africa and what informants do these provide for urban water management?
2. How are urban water resources currently managed within Cape Town?
3. Is WSUD a viable alternative to current urban water management approaches in Cape Town?
4. Can spatial planning be used as a mechanism to implement WSUD and catalyse a systemic transition in urban water management in Cape Town?

5. Can the principles of WSUD be implemented within spatial development plans for the development of the River Club in a manner which promotes sustainable development, increases the resilience of local communities whilst simultaneously addressing numerous national and local objectives?

Research Objectives

1. Review current national and local water related legislation, policy, institutional arrangements and management approaches to identify the informants they provide for urban water management within South Africa.
2. Explore the nature of the urban water cycle and the management thereof within Cape Town.
3. Explore WSUD as an alternative approach to current urban water management in Cape Town.
4. Explore spatial planning as a means to implement WSUD and catalyse a systemic transition in urban water management in Cape Town.
5. To demonstrate, by means of a case study of the proposed development of the River Club, the capacity of spatial planning to implement the principles of WSUD within a spatial plan to promote sustainable development, increase resilience within local communities and address multiple national and local economic, social and environmental objectives.

Ethical Considerations

This research does not contain any information of a personal or sensitive nature. The author is aware of ethics in research and the high ethical standards held by the University of Cape Town which it expects all students to uphold when conducting research. The research, and research methods, herein maintains and upholds these ethical standards and considerations throughout. A copy of the ethics clearance for this dissertation is attached to this document under Appendix A.

Research Method:

A qualitative research method is used as a means of information gathering within this dissertation and is the predominant method utilised within the case study research strategy. Attride-Stirling (2001) notes the increasing popularity of this form of research particularly as a means through which to conduct thematic analyses. Lingard & Kennedy (2007) maintain that qualitative research methods exhibit and enable authenticity in their findings through the facilitation of researching complex systems in a defined context. Frechtling (2002) suggests that qualitative research is best suited within research where formative evaluations are conducted as a means to consider the overall performance of a specific programme or project. This is highly applicable in evaluating the performance of water management strategies and approaches within South Africa and Cape Town. A qualitative research approach facilitates the analysis of, “large bodies of descriptive data”(Frechtling, 2002:44) which is a component inherent to the research conducted herein. There are numerous data collection methods inherent to a

qualitative research approach. The data collection methods employed within this dissertation are document studies and a case study which are discussed in greater detail below.

Empirical research is also incorporated as research method within this dissertation. This research method is defined as research, “relying upon or derived from observation”(Barr & Feigenbaum, 1981:2). Empirical research incorporates the formation of a series of research questions which are addressed through research via means of a literature review and a variety of research materials incorporating observations by the author (Schneider, 2005). The findings are then analysed to adequately address the research questions (Schneider, 2005).

Research Strategy

Case Study:

A case study of the proposed development of the River Club is used as a research strategy within this dissertation. Frechtling (2002) indicates that, “case studies can provide very engaging, rich explorations of a project or application as it develops in a real-world setting”(Frechtling, 2002:61). Hartley (2004) notes that there is a general trend toward increased application of case study research particularly within the social sciences. This is, in part, due to an increasing confidence in the academic community of the capacity of case studies, through a strategy which reflects rigorous research, to produce valuable information (Hartley, 2004). Case studies enable the generation of context dependant knowledge which promotes the identification of the interactions between multiple factors within and between the systems under study and provides a high level of detail through the provision of insights deeper than would otherwise be gained. The overall aim of this strategy, “is to provide an analysis of the context and processes which illuminate the theoretical issues being studied”(Hartley, 2004:323).

The case study conducted herein is a means through which to explore the incorporation of WSUD within spatial planning more specifically within a development of a spatial plan for the proposed development of the River Club. The resultant plan is expressed as a conceptual model as a result of the limitations within this research. This strategy, within the context of this dissertation, provides an exploratory platform through which to demonstrate the proposals put forth within the research. The case study presented within this research is not utilised as a means to test a hypothesis, as such a series of research questions are presented and addressed within the research and frames the study. A qualitative method of information gathering is used for the case study herein presented. This method has been elaborated upon above as the dominant research method.

Research Techniques and Data Collection

Document Studies

Document studies consisting of information gathering from a variety of existing literature, policy and reports have been used as the predominant data collection method within this dissertation. The

analysis of these documents provided in-depth insights into the various themes and structures explored that would not be possible via an alternative research method. A 'document' within the context of this research follows the definition provided by Lincoln & Guba (1985) as, "any written or recorded material"(Lincoln & Guba, 1985:277). This is an extremely broad definition and adequately encapsulates the wide array of written material from which information was gathered throughout the discourse of this dissertation. The main advantages of collecting information through documents studies include ease of access and availability, their unobtrusive nature, a useful way of highlighting and identifying trends and the often context specific nature of these documents (Frechtling, 2002). These advantages combine to enable a cost effective means through which to study context specific factors including local political, economic, social and environmental conditions (Frechtling, 2002).

Desktop Analysis

Desktop analyses are used to gather data and information throughout the discourse of this research dissertation. Analyses of relevant documentation and literature including water management plans and policy, and the analysis of aerial photographs will contribute to gaining a better understanding of the water management challenges and strategies within South Africa and Cape Town. Thorough reviews of documentation pertaining to the management of national and urban water resources are conducted. Desk-top studies thus facilitate the collection and analysis of qualitative data.

Literature Review

A literature provides a point of departure for this dissertation in that it provides a critical assessment of the existing literature on issues pertaining to this research. The literature is used as a means to highlight knowledge gaps in existing literature and to broaden the authors understanding of relevant topics. The literature review within this dissertation explores the notion of sustainable development and water sensitive cities.

Research Outcomes

There are four major outcomes of this dissertation.

- 1) The first outcome is an in-depth review of national water legislation and policy, how these inform urban water management, and a review of urban water management within Cape Town and its associated issues.
- 2) The second outcome is the consideration of WSUD as an alternative approach to urban water management in Cape Town.
- 3) The third outcome is the presentation of a model through which WSUD could be successfully implemented in Cape Town as a means to catalyse systemic change in urban water management.

- 4) The final outcome is the development of a conceptual spatial development framework (SDF) through a case study in which the proposal in outcome three is applied to promoting the principles of WSUD within the spatial planning process for the development of the River Club.

Limitations

The scope for primary data collection is drastically reduced given the 5 month time frame in which this dissertation is to be completed. This limited time frame has also placed restrictions on and limitations on the overall investigative scope of this research limiting various other forms of data collection and analysis. These constraints have drastically limited the incorporation of the ideas of various stakeholders, including members of the public, within this research. Qualitative research, particularly pertaining to document studies, presents a number of limitations and disadvantages which include the possibility of inaccuracies contained within documents, the challenge of locating appropriate documents, possibilities of incomplete documents and time consuming nature associated with document analysis (Frechtling, 2002). It is noted that various national, provincial and local governmental documents may not be readily available and accessing these documents may either not be permitted or require time consuming processes. Document studies can result in generalisations and present risks of overinterpretation, the author is aware of these potential negative outcomes (Frechtling, 2002). Desk-top analyses have numerous limitations especially in the context of this dissertation where proofing findings through field work and primary data collection is limited.

Case studies present numerous limitations in their application for knowledge generation. The context-specific nature of case studies results in a high possibility that findings within may not be applicable beyond the scope of the study and case study research must be cautious to not generalise these findings. Case studies do not present an adequate means through which to test hypotheses as such a case study is used herein as a means to investigate a number of research questions. The time limitation and reduced capacity to collect primary data, reduced the capacity to incorporate processes of public participation and stakeholder engagement within the research methods. As a result the case study aims to produce a conceptual spatial plan for the River Club which should in no way be interpreted as a final spatial proposal for the development.

The limitations of this research will be addressed through the analysis of formal legislation and policy documents along with peer reviewed academic reports to enhance the legitimacy of the claims and ideas put forth herein. Furthermore the author will be aware of the propensity to over generalise and overinterpret certain information contain within various documents. The author's ideas are expressed as conceptualisations or proposals and should not be regarded as definitive. This research merely presents a number of ideas which will require more rigorous, in-depth, study.

Chapter Outline

- Chapter 2: A review of existing literature which relates to the research interests herein presented is provided in Chapter 2. The literature review explores the ideas of urban systems, sustainable development, water sensitive cities and the ways in which systems management within cities can contribute to enhancing resilience within local communities in creating long-term sustainability. The literature review provides a point of departure for the research presented herein and its use provides the author with deeper insights into the existing knowledge base pertaining to the topic and provides a means through which to identify potential knowledge gaps within the literature.
- Chapter 3: Chapter 3 provides an in-depth review of WSUD so as to gain insights into this form of water management and the conditions it requires to be successfully implemented within urban areas. The chapter identifies the principles and framework inherent to WSUD and the role of spatial planning within this framework. In addition, the chapter outlines the application of this approach within Australia and indicates the successes it has achieved within the country via the use of two case study examples.
- Chapter 4: Chapter 4 reviews water management at a national level throughout South Africa as a means to highlight the informants this legislation, policies and strategies provide for the management of water resources within urban areas. The chapter highlights the link between water management and the need for development and sustainability within South Africa in order to frame the necessity of water resource management at a national, provincial and local level. Policy pertaining to various spheres of water management is reviewed so as to gain a perspective of national conditions and the roles of responsibilities of national, provincial and local governance structures and institutions with regards to these various management approaches. The role of water in promoting sustainable growth and development is considered and the various contemporary issues with regard to the management of this resource are identified.
- Chapter 5: Chapter 5 focusses on urban water management with an intent focus on Cape Town's urban water cycle and the management of its urban water resources. The need for effective and efficient resource management is discussed as a means to promote sustainable development within the city. The current urban management approach by the CoCT is reviewed and a host of major contemporary management concerns are identified. The chapter concludes with the consideration for an alternative approach to urban water management in Cape Town.

- Chapter 6: This chapter considers WSUD as an alternative urban water management approach which could be adopted by the CoCT as a means to alleviate current management pressures. The chapter considers the capacity of WSUD to enhance water management in Cape Town and the potential benefits it could provide through a holistic management approach which protects valuable water resources and promotes sustainable development. The challenges to implementing the principles of WSUD within the CoCT's water management framework are highlighted.
- Chapter 7: The catalysing of a systemic transition through spatial planning is considered within this chapter. Ideas around incorporating the principles of WSUD within spatial planning as a means to overcome the numerous challenges in implementing this approach within Cape Town are considered. The capacity of spatial planning in this endeavour is considered in-depth, to further explore its potential influence in transforming urban water management in the city. A proposal for a new model through which to implement WSUD is provided.
- Chapter 8: Chapter 8 applies the ideas presented in Chapter 7 by means of a case study of the proposed development of the River Club. The case study explores the application of the principles of WSUD within spatial planning. It indicates how these principles can be used to inform spatial plans and facilitate the achievement of numerous spatial objectives. The study highlights the ability of WSUD to target multiple objectives simultaneously in enhancing water management by increasing the efficiency of the urban water metabolism. As a result the case study indicates how WSUD can increase resilience within a development and promote sustainable development whilst simultaneously addressing numerous spatial objectives and further informing the spatial planning process. The outcome of this chapter is a conceptual SDF for the River Club development.
- Chapter 9: This chapter provides a discussion in which the ideas and findings of this research are synthesised to provide an overview the dissertation. The chapter discusses the links between the various chapters and notes the significance and potential benefits of this research for Cape Town.
- Chapter 10: The chapter outlines the major recommendations set forth within this dissertation along with recommendations for future studies. The chapter provides an overall conclusion to the dissertation in its entirety.

Conclusion

Chapter one has provided a comprehensive outline of the research to follow framing the research problem, highlighting the research questions and objectives, the methods used to respond to these, the limitations of this research and the expected outcomes. The introduction has provided the necessary context in which this dissertation is situated and an outline of the various chapters has indicated how this research unfolds. To follow is research designed to guide enhanced water resource management in Cape Town. The philosophical and ethical views maintained by the author serve to guide this research to promote sustainable development and address multiple spatial objectives contained in national and local policy.

Chapter 2: Literature Review

Introduction

This literature review aims to consider a host of terms, concepts, studies and additional existing information and knowledge relevant to the focus of the research conducted within this dissertation. The review of these topics will inform the author and the research herein conducted, and highlight existing knowledge gaps within the literature. The literature considered within this review includes information surrounding the debates on the enhanced sustainability of cities. These debates include varying ways of considering and defining sustainability and numerous concepts and conceptual models which can be used to advance understandings of urban systems. The debates considered within this literature review include the need for considering urban systems and management of these systems to increase the resilience and sustainability of cities. The need for transformative approaches to systems management is considered in conjunction with the notion of systemic transitions. Particular attention is paid to the urban hydrological cycle and the concept of urban water metabolism. The review aims to identify existing knowledge pertaining to management strategies that can be implemented to create increased sustainability and resilience. The review aims to situate spatial planning and urban design within the context of these debates and identify the capacity of these disciplines in addressing a variety of goals and objectives.

Sustainable Cities, Resilience and the Global South

As a result of high rates of urbanisation and the exponential increase in urban populations, urban areas, the features that characterise them, and the way in which they are planned and managed are of increasing international interest (Rana, 2009). Rana (2009) notes that creating a state of sustainability within a city is a significant challenge especially within cities of the global south. These cities are found in the world's developing countries and are often associated with high levels of poverty, limited resources, insufficient and/or failing infrastructure, political instability and inadequate public institutions (Watson, 2014).

The WCED (1987) defines sustainable development as, "development which meets the needs of the present without compromising the ability of future generations to meet their own needs"(WCED, 1987:43). Rana (2009) argues that the use of sustainable development as a 'buzzword' has led to multiple interpretations and definitions of term which has ultimately resulted in confusion as to what the term actually stands for. Despite this confusion, the definition by the WCED (1987) is still accepted as the dominant definition. Hall (1998) argues that this definition, despite its widespread use, lacks clarity particularly in its use of the term 'needs' which are not clearly defined. This has left much open for interpretation as to what 'needs' this definition is referring to. Furthermore, the needs of cities of the global south differ significantly from those of the global north, as a result Rana (2009) argues that,

“the vision of sustainable city based on sustainable development”(Rana, 2009:507) lacks clarity and is left open to numerous interpretations.

Global environmental concerns are largely contained within Agenda 21 and the Brundtland’s Report. Agenda 21 was conceived in 1992 at the Earth Summit in Rio de Janeiro highlighting the numerous challenges inherent to the promotion of sustainable cities through sustainable urban development (Rana, 2009). The Brundtland’s Report which promotes enhanced management of resources, greater natural resource conservation, and increased focus on the natural environment in terms of development planning is viewed by Rana (2009) as highly idealistic. Cities around the world are developing goals through which to achieve a state of sustainability based on the notion of sustainable development, however it has been argued that, “the level of attention directed to the principles of sustainable development is less widespread in contrast to implementation of policies to achieve sustainable development”(Pacione, 2007). This indicates that the principles through which sustainable development should be promoted are being largely overlooked within policies and management approaches.

The Brundtland’s Report has been widely criticised for its lack of recognition of the vast differences that exist between cities of the global north and cities of the global south in terms of available resources which are largely skewed to the North (Rana, 2009). Atkinson (2004) notes that, “no significant recommendations were made concerning the redistribution of resources between the countries of the north and south”(Atkinson, 2004) given the high levels of inequality (Rana, 2009).

Economic growth and development is a central focus by governments’ around the world and many in the global north maintain this can be achieved concurrently with sustainable development. Negative environmental impacts are inherent to economic growth and development however these impacts can be minimised through various sustainable practices (Rana, 2009). Cities of the global south are faced with the challenge of promoting much needed economic growth and development through practices which are internationally regarded as sustainable. This challenge is one which was not faced by many cities of the global north in the promotion of urban development.

The ultimate goal of sustainable development is to create a sustainable city. As with sustainable development there are numerous definitions for a sustainable city. These definitions include a city which is, “organized so as to enable all its citizens to meet their own needs and to enhance their well-being without damaging the natural world or endangering the living conditions of other people, now or in the future”(Girardet, 1999) and, “one in which its people and businesses continuously endeavor to impose their natural, built and cultural environments at neighborhood and regional levels, whilst working in ways which always support the goal of global sustainable development”(Haughton & Hunter,

1994:27). A focus on local social, economic and environmental conditions within an urban environment are significant in the promotion of a sustainable city. Sustainable development maintains that a balance must be achieved between the need for economic growth and development and, social concerns and environmental needs, to create a state of long-term sustainability.

Rana (2009) highlights numerous challenges inherent in creating a city which is sustainable in nature, noting that cities are 'dynamic' and thus must focus on multiple solutions in order to create such an environment. Furthermore, sustainable solutions in one city may not be applicable to another thus lessons learnt within the global north are often not transferable to cities of the global south and so too solutions may not be transferable between cities of the global south (Rana, 2009). Swilling (2010) found that there is little literature which takes into account challenges inherent to the developing world and which provides cities of the global south with a discourse for action for the development of a sustainable city. Myllyla & Kuvaja (2005) note that, "approaches to urban environment that have originated for the North carry inherently northern connotations and policy solutions that may have particular constraints when scrutinizing sustainable developments societal context in the South"(Myllyla & Kuvaja, 2005:224). Rana (2009) thus argues that, given the vast differences between the cities of the world in terms of social, economic and environmental conditions, sustainability should not be viewed as a principle or goal and should be used as a means of promoting social justice and equality.

A lack of financial resources, human capacity, adequate governance and sustainable planning are typical of cities within the global south however Swilling (2010) maintains that most literature focusses predominantly on issues pertaining to the natural environment and the use of resources without taking these factors into account. The developing cities of the global south are characterised by inadequate service provision which includes transport, housing, sanitation and water (Gandy, 2006). McFarlane (2010) notes that infrastructure within these cities is often, "synonymous with breakdown, failure, interruption, and improvisation"(McFarlane, 2010:131). Within these cities there are varying degrees of infrastructural interruption, which range from large scale crises such as natural disasters to smaller scale interruptions which include power outages and contamination of drinking water (McFarlane, 2010). McFarlane (2010) highlights that these small scale interruptions receive little interest within urban studies, despite their negative impacts on local populations. These interruptions in urban infrastructure within cities of the global south are generally a product of a lack of resources which results in little to no maintenance of existing infrastructure or improvements to the cities infrastructural networks (McFarlane, 2010).

McFarlane (2010) links the distribution of urban infrastructure throughout cities of the global south to concerns of inequality. This inequality is both exacerbated, and caused by, the distribution and state of urban infrastructure. The urban poor are often most at risk to the adverse effects of natural disasters such as flooding largely because of the fact that the level of infrastructure which they have available to them is unable to cope with these conditions. It is either inadequate by design, limited in capacity, structurally unsound due to age or a combination of the three. The infrastructure supplied to the urban poor such as those which support service delivery, i.e. sanitation, water and electricity, are, in many cases, inadequate, outdated and, in some cases, completely absent. It is in this way, as noted by McFarlane (2010) that urban infrastructure can further exacerbate concerns of inequality in urban areas.

Revell (2010) notes the need for the promotion of resilient cities; this includes resilience against potential threats including: a changing climate, natural disasters, political change and instability, economic instability and other unpredictable internal and external changes. Revell defines resilience as, “the adaptive capacity of a system and a measure of the systems vulnerability to unexpected shocks and unpredictable changes”(Revell, 2010:2) while Pickett *et al* (2004) maintain that resilience is, “the ability of a system to adapt and adjust to changing internal or external processes”(Pickett *et al*, 2004). Resilient cities can thus be defined as those which are capable of adapting and adjusting to stimuli which bring about change generated either internally or externally (Revell, 2010). Cities which exemplify resilience are thus less susceptible to threats as they exhibit adaptability and reduced vulnerability. Revell (2010) notes that cities must be planned and designed in a manner which promotes resilience in a manner which is economically, socially and environmentally sustainable in turn promoting social, economic and environmental resilience.

Infrastructure can be utilised as a means to create resilience among communities within cities of the global south. Chirisa *et al* (2016) indicate the need for resilient infrastructure within cities throughout Africa in light of climate change concerns. Resilience here is defined as “the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change”(Chirisa *et al*, 2016:113). This notion of resilience has been linked to the movement toward sustainable development largely with regard to increasing resilience to natural disasters exacerbated by climate change (Chirisa *et al*, 2016). Chirisa *et al* (2016) indicate that a major drawback within African cities in achieving sustainable development through resilient infrastructure, is largely at an institutional level pertaining to issues such as corruption and inadequate capacity. An additional drawback noted, is the lack of participatory approaches which include local community members and other stakeholders (Chirisa *et al*, 2016).

Sustainable development is defined, for the purpose of this dissertation, as development which promotes equitable economic and social growth and development in a manner which does not jeopardise the integrity and functioning of the natural environment. Development targeted in this manner upholds the definition by the WCED (1987) discussed above. The management of urban systems and natural resources within the urban environment is key in promoting sustainability and resilience.

Urban Systems

Urban areas are comprised of a complexity of systems operating and interacting with one another at a variety of spatial scales (Pumain, 2004). Van Der Laan (1998) notes that urban systems change continuously at a variance of spatial scales largely as a result of internal and external stimuli. Louis *et al* (2017) indicate that “urban systems are comprised of the processes by which life in metropolitan areas is organized and operated”(Louis *et al*, 2017). Systems within urban areas are a diverse and complex series of economic, social and environmental processes intrinsically linked through space and time undergoing continuous change as the city evolves. The urban water cycle is one such system which must undergo constant change to cope with increases in demand for water resources as a result of growing urban populations (Mitchell *et al*, 2001). Marsalek *et al* (2008) note that the urban water cycle, similar to other urban systems including the supply of electricity and transportation networks, must contend with the increase in numerous social, economic and environmental demands as a result of urban population growth. The increasing demand for resources and the increased productions in waste have profound impacts on social, economic and environmental systems (Marsalek *et al*, 2008). Marsalek *et al* (2008) note that conflicts which arise within cities as a result of increased demand for a variety of resources, necessitate a management system which reflects high degrees of integration. The inherent interactions between urban systems require coordinated management to promote and achieve sustainable outcomes whereby the effectiveness and efficiency of these systems are not compromised so as to support generations to come (Marsalek *et al*, 2008).

The urban water cycle is a complex system which is impacted upon and impacts on a wide variety of social, economic and environmental factors. Marsalek *et al* (2008) maintain that, “Analysis of urban water management should be based on the urban water cycle, which provides a unifying concept for addressing climatic, hydrologic, land use, engineering, and ecological issues in urban areas”(Marsalek *et al*, 2008:2). The hydrologic cycle can be defined as, “a conceptual model describing the storage and circulation of water between the biosphere, atmosphere, lithosphere, and the hydrosphere”(Marsalek *et al*, 2008:2). This is a highly complex system which involves processes including precipitation, runoff and condensation to circulate water. The characteristics of the hydrologic cycle are modified by urban areas further exacerbated by urbanisation and population growth (Marsalek *et al*, 2008). Despite these

modifications the fundamental nature of the hydrologic cycle remains intact and when in contact with urban areas, is referred to as the urban water cycle.

The urban water cycle is a distinct hydrological system in that the interactions of the urban environment and natural hydrological functioning produce conditions under which hydrologic functioning is altered (Marsalek *et al*, 2008). The urban water cycle alters natural hydrological functioning through a combination of activities including abstraction for water supply, wastewater generation and stormwater drainage (Marsalek *et al*, 2008). The complex nature of the urban water cycle requires high levels of management to address multiple economic and social objectives in a manner which does not jeopardise the integrity of the natural environment.

Managing the Urban Water Cycle

National, provincial and local legislation, policies and institutions guide urban water management. Management activities include the collection and storage of water resources, transport of water to consumers via treatment facilities, the treatment and subsequent release of wastewater and stormwater management (Coombes & Kuczera, 2002). Current approaches to urban water management are characterised by compartmentalisation of management responsibilities delineating processes of stormwater management, WWT and water supply (Coombes & Kuczera, 2002). This results in failure to regard the urban water cycle as complex system in which all components are intrinsically linked interacting with one another in processes which cannot be separated (Coombes & Kuczera, 2002). The uncoordinated nature of contemporary approaches to urban water management has resulted in negative environmental impacts, concerns for public health through high rates of water pollution, costly infrastructure upgrades, rapid removal of valuable stormwater resources and a host of additional economic, social and environmental impacts.

The need for a more sustainable approach to urban water management is driving the necessity to consider the complexities of these systems and to respond by taking a 'systems approach' to the management of urban water resources (Hellström *et al*, 2000; Coombes & Kuczera, 2002). The 'systems approach' incorporates the complexities associated with urban water management and accounts for the conflicts which exist between the numerous objectives pertaining to economic, social and environmental protection and development (Coombes & Kuczera, 2002). A systemic transition is required to effect such a shift in urban water resource management.

Systemic Transitions to Sustainable Water Management

The rapid growth of urban areas and the inherently high rates of resource consumption have placed these urban areas as central to concerns surrounding sustainability. Nevens *et al* (2013) indicates that this has placed pressures on cities around the world to generate policies which seek to shape the

management of resources in a manner which reflects global sustainable resource use. The scope of the responsibilities of local government has, as a result, widened to address concerns of sustainability requiring multilevel governance structures given the complexities inherent to urban systems (Hodson & Marvin, 2012). Cities in developed countries possess the necessary resources to restructure urban systems in a manner which reflects sustainability through amendments to legislation, policy reform, and, if necessary, institutional restructuring. Limited resources, which characterise local governments within many developing cities, result in a lack of capacity to adequately restructure urban systems to reflect sustainability (Nevens *et al*, 2013). The capacity of developing cities to influence change within urban systems is thus drastically reduced and, as a result, these cities cannot rely solely upon local government to bring about systemic transitions.

Urban transitions discussed within existing literature, particularly those that focused on sustainability, often pertain largely to ways in which to reduce carbon dioxide (CO₂) and other greenhouse gas (GHG) emissions through reforms in urban transportation and energy provision. “Transitions are considered as societal processes of fundamental change in culture, structure and practices”(Nevens *et al*, 2013:112). The notion of an urban transition in its contemporary context is one which directly addresses sustainable development and Eames *et al* (2013) note that that transitions within urban infrastructure and systems management are required to address increasing resource constraints largely as a result of growing urban populations and climate change. Systemic change, through various innovative processes and solutions, is central to transitions and often involves new infrastructure, technology, institutional arrangements, management approaches and policy. Transitions are regarded as long-term processes largely as a result of the inherent nature of interactions between stakeholders, institutions and policy which require coordination and must evolve simultaneously to ensure systemic efficiency and effectiveness (Nevens *et al*, 2013). Research has indicated that urban transitions can be catalysed by numerous stimuli including changes in people’s attitudes and ideals, and technological innovation and advancement (Nevens *et al*, 2013). Urban areas exhibit a large capacity for innovation within technological, infrastructural and management systems (Ernstson *et al*, 2010). Innovation is the key driver behind sustainable development and, by extension, a major driver of urban transitions (Ernstson *et al*, 2010). Van Buuren & Loorbach (2009) maintain that preliminary projects designed to evaluate the effectiveness and efficiency of a new approach can catalyse a systemic transition by promoting policy development (Nevens *et al*, 2013). This indicates that bottom-up approaches can be utilised as a means through which to promote the transition of urban systems.

Studies to date on systemic urban transitions have focused largely on systems pertaining to energy production and consumption and urban transportation (Nevens *et al*, 2013). In addition, focus has been largely on analysing urban transitions in contrast to identifying a discourse for action in guiding a

transition (Nevens *et al*, 2013). Nevens *et al* (2013) highlight a number of challenges inherent to transforming a system and bringing about an urban transition. The first major challenge pertains to addressing issues which transcend scales and boundaries. Systems, including the urban hydrological cycle, operate at multiple scales and transcend numerous boundaries including boundaries linked to specific sectors, governance structures, policies and those of other systems (Nevens *et al*, 2013; Ernstson *et al*, 2010). The second major challenge of bringing about an urban transition also pertains to scale, more specifically to the ability of an intervention to be up-scaled so as to display a city wide impact. The question here remains, “what are the governance mechanisms that can enable the scaling-up and empowerment of urban innovations for sustainability?”(Nevens *et al*, 2013:113). The final challenge is that of time. The pertinent need for sustainable development has resulted in requirements to find solutions to creating systemic transitions which can be implemented in the short-term. Localised action can be a strategy through which to implement immediate localised systemic change which can then be up-scaled over time to effect systemic change at an urban scale so as to bring about long-term sustainability (Nevens *et al*, 2013).

Brown *et al* (2009) consider the historical context of urban water management in transitioning to more sustainable management practices indicating six stages of management transitions.

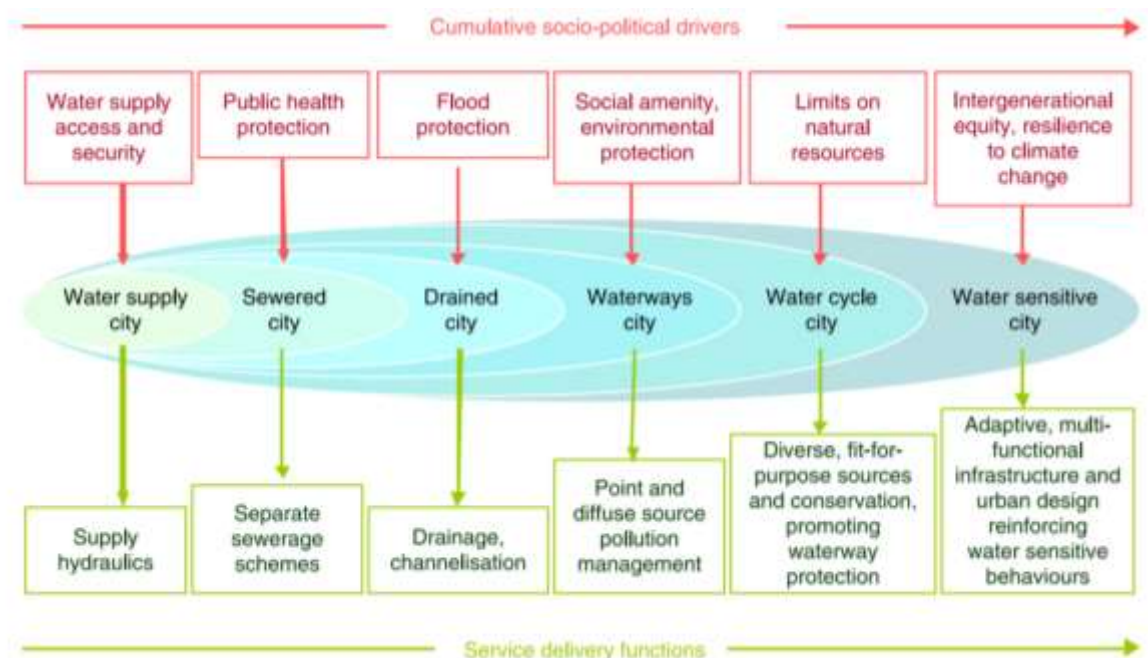


Figure 1: Urban Water Management Transitions to Enhanced Sustainability (Brown *et al*, 2009:850)

Brown *et al* (2009) note that the transition in urban water management from one state to another involves transitions in water policy which then guide the required change in management approaches

to effect and overall transition in water management. The capacity of a city to undergo a transition in urban water management, and the rate at which this transition occurs, is dependent on numerous factors including socio-economic, biophysical and socio-political conditions (Brown *et al*, 2009). The development of a 'transitions framework' by Brown *et al* (2009) is seen as a mechanism through which the transfer of information between cities. It is noted that as a city moves between the varying states of water management the objectives of the management strategies change and evolve and, in some cases, may be in conflict with previous objectives (Brown *et al*, 2009). It is also noted that, although presented as linear change, it is possible for a city to skip various stages or revert back to a former management paradigm (Brown *et al*, 2009).

The framework presented by Brown *et al* (2009) is highly conceptual, furthermore, these studies were conducted in Australia where socio-economic and socio-political factors differ vastly from those experienced within developing cities. Despite indicating a historical progression of transitions in urban water management toward more sustainable practices there is little mention of how these transitions are effected. New institutionalism is discussed as a means through which to study and further understand change at an institutional level. Institutions, it is noted, are comprised of a combination of 'hard' and 'soft' infrastructure which, under new institutionalism, incorporate institutional structures, legislation and governmental departments as 'hard institutional infrastructure' and administrative actions and social interactions as 'soft institutional infrastructure' (Brown *et al*, 2009). Brown *et al* (2009) maintain that institutions are comprised of three pillars namely; cognitive, normative and regulative, all of which shape institutional functioning. These pillars involve the skills and knowledge, values sets, and rules and regulations respectively (Brown *et al*, 2009). International drives to protect environmental resources have seen increased targeting of sustainable urban water management (SUWM) practices. It is noted that in order for a systemic transition to occur in the management of urban water resources, institutional change is required which must involve, "a mutually reinforcing shift within each of the pillars of institutional practice"(Brown *et al*, 2009:848). The conditions under which these transitions are effected would be expected to differ between developed and developing countries as per the reasons previously discussed.

Water Sensitive City/Settlement

Farrelly & Brown (2011) note that support for new ways in which to manage urban water resources is widespread, particularly toward more sustainable practices. Brown *et al* (2008) provide evidence which indicates that urban water management challenges change as the urban area evolves over time, thus giving rise to new urban water management strategies.

Brown *et al* (2008) & Wong & Brown (2009) note a worldwide shift toward more sustainable approaches to the management of urban water. This change has been triggered largely by increased demand as a product of rapid population growth within urban areas, degradation of the natural environment and enhanced changes in Earth's climate system (Brown *et al*, 2008). Wong & Brown (2009) suggest that failures to respond to these challenges within the paradigm of urban water management is largely as a result of traditional approaches which treat different components of urban water management such as supply, drainage and sewage as separate entities. The compartmentalised arrangement of these management areas is viewed by Wong and Brown (2009) as a major inhibiting factor in achieving sustainability, resilience and promoting a water sensitive city. It is noted that these are shared issues between inadequate infrastructure and institutional arrangements (Wong & Brown, 2009).

Gleik (2003) maintains that despite technological advancement and changes in social values in favour of sustainability, it is a lack of adequate policy informant tools which is currently hindering progress toward SUWM. Brown *et al* (2008) note the lack of a clear vision as an additional hindrance. Farrelly and Brown (2011) argue that failure in this endeavor is largely associated with poor governance frameworks. It is noted that more dynamic, inclusive and flexible governance structures are required in order to promote sustainable water management and by extension a water sensitive city (Farrelly and Brown, 2011). Despite numerous concepts such as WSUD and integrated urban water management it is still largely unclear what constitutes a water sensitive city.

There is no clear definition on what constitutes a water sensitive city (Brown *et al*, 2008: Wong & Brown, 2009). Despite this Wong & Brown (2009) propose that a water sensitive city is comprised of three 'pillars' namely; 1) the city as a catchment responsible for water supply via infrastructure (both decentralised and centralised), 2) provision of ecosystem services (ESS's) within cities, and 3) 'water sensitive communities' within cities. Costanza *et al* (1997) note that, "ecosystem goods and services are the benefits that humans derive (directly and indirectly) from naturally functioning ecological systems"(Costanza *et al* 1997:4).

Brown *et al* (2008) maintain that, despite increasing interests in the concept a water sensitive city, there is not one example on Earth today. In the development of this relatively new concept Brown *et al* (2007) indicate that a water sensitive city should promote resilience, mitigation against natural disasters, environmental protection and sustainability, concerns of liveability, human health and well-being, equality, and economic prosperity.

Brown *et al* (2008) conclude that there is a dire need for innovative ways in which to manage urban water resources in a manner which promotes long-term sustainability. Wong & Brown (2009) indicate

that investment needs to shift away from traditional compartmentalised management approaches toward alternatives which promote water sensitivity and sustainability.

Ferguson *et al* (2013) identify a programme which can be adhered to in attempting to transition to the more sustainable state of a water sensitive city. The ideas in this research are in alignment with those of Farrelly & Brown (2011) in the recognition that for a city to achieve a water sensitive state an adaptive approach to urban water management is required. This new approach requires a shift in urban design, urban planning and governance structures. The 'strategic programme' set forth in this research aims to guide 'long-term urban infrastructure management' which is believed to be a key component of achieving a water sensitive state (Ferguson *et al*, 2013).

Wong & Brown (2009) indicate that amongst the emerging water management concepts, WSUD has received a great deal of attention as a means in which to promote the achievement of a water sensitive city. This concept integrates urban design with 'integrated urban water cycle planning and management' promoting an interdisciplinary approach to urban water management.

Urban Metabolisms

The notion of an urban metabolism was first conceived in 1965 by Wolman and was defined as "all the materials and commodities needed to sustain the city's inhabitants at home, at work and at play"(Wolman, 1965, Revell, 2010:3). Numerous researchers have conducted studies on the concept of urban metabolism since the study undertaken by Wolman (1965). Similar to many other fields of study, the concept of urban metabolism has undergone an evolutionary process from its first inception to its contemporary understanding. Wolman (1965) considered a limited set of urban metabolic attributes, among these were a range of pollutants and sources of waste, food and water consumption within an urban area. Despite neglecting to include attributes such as various infrastructural considerations this study brought to light the process of consumption, production and the associated waste created within urban landscapes.

The study of urban metabolisms was considered one which required a transdisciplinary approach when, in the 1970's, as noted by Kennedy *et al* (2011), separate studies were conducted by chemical engineers (Kennedy *et al*, 2011), ecologists (Duvigneaud and Denayeyer, 1997) and civil engineers (Newcombe *et al*, 1978). These studies began to consider a wider range of attributes within the context of an urban metabolism. All three exhibited a unique area of focus which had not, until that point, been considered. In addition, numerous researchers in the 1970's were beginning to describe urban metabolism "in terms of solar energy equivalents"(Kennedy *et al*, 2011:3). Despite the fact that this is no longer incorporated in contemporary metabolism studies research conducted by Zucchetto (1975) on the

urban metabolism of Miami, and Odum (1983) on data collected in the mid 1800's from Paris, are regarded as important pieces of literature with regard to studies of urban metabolism.

The momentum created within this field of research appeared to decrease slightly through the 1980's and 90's. A key piece of literature was a study produced by Bohle (1994) which considered food systems within the urban environment and the impact of this system on urban metabolism. The notion of a sustainable city was focused upon in the early 90's by Girardet (1992) who began to examine the role of urban metabolism in creating sustainable urban environments. Baccini and Brunner (1991) began to consider the concept of material flow analysis (MFA). MFA consider inputs and outputs in terms of their mass. The importance of this is the shift away from focusing on inputs and outputs as energy (Kennedy *et al*, 2011). This is an important point in the evolution of urban metabolic studies as more practical units began to be used in contrast to those of energy used by Zucchetto (1975) and Odum (1983).

The turn of the century marked an important reinvigoration in the study of urban metabolisms. Studies by Newman (1999) and Baccini (1997) focused on Sydney's urban metabolism and a MFA for the European city of Vienna respectively. Newman (1999) began to consider additional attributes within the study of urban metabolisms to include indicators of *liveability*. It was proposed that, "an extended metabolism model, which included indicators of health, employment, income, education, housing, leisure, and community activities"(Kennedy *et al*, 2011:4) be included in the field of study. Kennedy (2007) later redefined the definition of the urban metabolism "as the sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste"(Kennedy *et al.*, 2007; Revell, 2010:3)

Kennedy *et al* (2007) considered processes of accumulation within in urban areas such as the storage of heat within various materials ranging from tar on roads and pavements to rooftops and the accumulation of water resources within urban aquifers. With regard to studies which focused largely on addressing water issues within cities significant contributions have been made by "Hermanowicz and Asano (1999), Gandy (2004), Theriault and Laroche (2009), Sahely and Kennedy (2007) and Baker (2009)"(Kennedy *et al.* 2011:4).

Kennedy *et al* (2011) indicate the concept of urban metabolisms to be imperative in endeavors to create sustainable communities. Newell and Cousins (2015) note that, "the city has organismic qualities in that it consumes resources to sustain itself, transforms energy, and eliminates waste"(Newell & Cousins, 2015:713). Kennedy *et al* (2007) define an urban metabolism as, "the sum total of the technical and socio-economic processes that occur in cities resulting in growth, production of energy, and elimination of waste"(Kennedy *et al*, 2011:1). The application of the study of urban metabolisms is deeply ingrained in measures to quantify both the inputs and outputs of processes that take place within cities. Kennedy

et al (2011) note that the study of urban metabolisms, despite not being a new concept, has gained momentum over the past two decades.

Many maintain that the fundamentals of the notion of an urban metabolism be conceived as a metabolism similar to that of a living organism whereby raw materials are consumed and, through numerous internal processes, waste is excreted (Kennedy *et al*, 2011). Decker *et al* (2000) maintain that external raw materials including fuel and water enter the city and through numerous internal processes are excreted as waste (Decker *et al*, 2000). For example, fuel enters the city as a raw material, the city metabolises that fuel (for instance in the use of a motor vehicle) excreting carbon dioxide as a waste product. The concept of urban metabolisms can be understood in various ways however, Kennedy *et al* (2011) indicate that the metabolism of a city can be as easily understood as an ecosystem.

Sustainable cities seek, to some degree, to mimic natural ecosystems as these systems are inherently self-sufficient in terms of energy and required external inputs are of a sustainable nature. If cities were to exhibit such qualities they would be regarded as sustainable systems. Kennedy *et al* (2011) indicate that this is extremely difficult to achieve given the complex nature of cities and the processes inherent to these systems. In addition, it is noted that the inputs and outputs of energy vary according to the size of a city and large urban centers today require large quantities of resources as inputs and give off large quantities of outputs collectively termed waste (Kennedy *et al*, 2011). Dodman (2009) indicates that much of this waste results in negative impacts upon the natural environment and human health thus further reducing the sustainability of a city.

Revell (2010) notes that the urban metabolism differs from that found in the natural environment in that they are more complex given human dominance and the inherent factors of this species which include the complexities of intangible facets such as emotions and value systems which differ from person to person. Thus urban metabolism must be thought of as a system more complex than a linear system of materials movement and must incorporate considerations of social and environmental justice, liveability, human health and wellbeing, enhanced creation of opportunities for all, among numerous other social, economic and environmental concerns (Revell, 2010). Revell (2010) argues that urban metabolisms can be indicative of the 'rate of change' within a city and can therefore be utilised as a measure of resilience. Resilience can be measured by this rate of change and the rate at which the city is able to adapt to this change (Revell, 2010). Revell (2010) maintains that the faster a city's metabolism the greater its resilience as the speed of the metabolism is proportionate to the city's ability to adapt to change.

Urban Water Metabolisms

Nuwell & Cousins (2015) consider the example of urban water resources as a means to discuss urban metabolisms. Desfor and Keil (2004) note that water is a well-documented field of study within Urban Political Ecology as it is bound within specified spatial areas and inputs and outputs of various hydrological systems which are often easily recognisable. The 'hydro social cycle' is an emerging field of research which takes into account various socio-political factors, such as institutions, social practices, and physical infrastructure, recognising these as inherent to the hydrological cycle particularly within urban areas (Bakker, 2003; Newell & Cousins, 2015). Industrial ecologists, when considering the 'urban water metabolism', would commence by delineating the boundary of the system. This delineation includes the identification of sources of supply and the movement of water through the defined area. Water resources would then be quantified by means of a 'life cycle assessment' (LCA) or a MFA (Nuwell & Cousins, 2015). The calculation of the carbon footprint of the water cycle, including the source and urban life cycle of the resource, involves the collection of data. The analysis and interpretation of this data provides results and information which informs numerous recommendations aimed at reducing carbon emissions (Nuwell & Cousins, 2015). These recommendations can be utilised to both inform and, if necessary, transform Infrastructural, institutional, technological and policy approaches and arrangements. This includes endeavors to source water from less carbon intensive sources and reducing carbon emissions in the treatment of water resources.

Hermanowicz and Asano (1999) considered Wolman's (1965) concept of the urban metabolism in relation to the re-use and recycling of urban water resources. The hydrological cycle within an urban area, which includes the supply of water, the discharge of water resources (both from natural systems and human use), and the re-use of water, is a component of the urban metabolism. Hermanowicz and Asano (1999) recognise the need, as exclaimed by Wolman (1965) for the urban metabolism to be a sustainable cycle so as to promote quality of life and environmental well-being.

Hermanowicz and Asano (1999) note that the hydrological cycle within an urban area exhibits a number of characteristics which are unlike any of the other commodities regarded within the urban metabolism. Wolman (1965) noted that the consumption of and associated waste water generated eclipsed the quantities of any of the other urban commodities. As such, water has a major role to play with regard to the urban metabolism.

Hermanowicz and Asano (1999) made two observations with regard to urban wastewater: wastewater is an underutilised water resource, and wastewater is a reliable water source even in times of drought. It was noted that the utilisation of this resource would invariably create a more sustainable urban metabolism and enhance resilience among local communities (Hermanowicz and Asano, 1999).

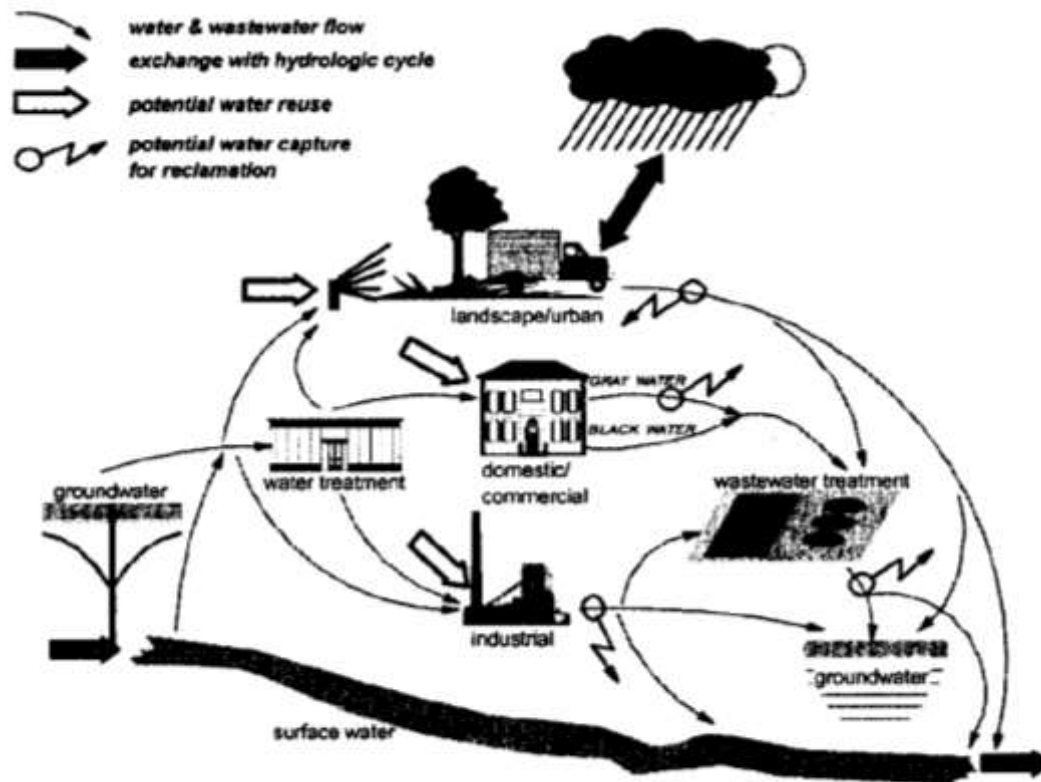


Figure 2: Diagrammatic Depiction of an Urban Water Metabolism (Hermanowicz and Asano, 1999:31)

Figure 1 is a simplistic diagram of the urban water cycle. The diagram indicates potential sources of wastewater for re-use. Hermanowicz and Asano (1999) identify a number of obstacles which are to be overcome in ensuring that water resources are used efficiently and effectively. Most of these obstacles pertain to public buy-in and institutional arrangements. There are of course the additional challenges of economic and infrastructural barriers the two of which, in many instances, overlap. Additional infrastructure is required and this is often an economic burden which, in most cases, is placed on the state. The study highlights a number of applications where wastewater can be re-used which includes; irrigation, industry and other applications which do not require potable water (Hermanowicz and Asano, 1999).

The re-use of urban water has received research attention around the world. Studies by Dillon (2000) and Lazarova *et al* (2001) focused on water resource re-use in Australia and Europe respectively. Numerous studies have been completed within South Africa. Adewumi *et al* (2010) studied the numerous challenges associated with water re-use in South Africa whilst Morrison *et al* (2001) considered a number of *sustainable development indicators* which can be used in relation to the urban water system.

Theriault and Larcohe (2009) attempted to quantify inputs and outputs of the 'urban hydrologic metabolism' for the city of Moncton, Canada. The results from this research were extremely beneficial and included information on water wastage areas and indicated in which sectors water losses were occurring. The analysis of this data and the associated information provided enabled the adoption of enhanced sustainability with regards to the management of urban water resources (Theriault & Larcohe, 2009).

Role of Infrastructure in Urban Metabolisms

Gandy (2004) considers the social implications of urban water management and claims that it can be either be a factor which generates increased social cohesion or creates conflict as a result of inequalities. Gandy (2004) examines the evolution of the urban water system from the 'industrial city' to modern day urban structures. Correlations between water resources and the 'urban space' are used to examine changes within urban structures, for example, new ideologies based on increased sanitation and cleanliness, and a move toward technocratic management structures in the form of municipal management. Urban infrastructure plays an important role in this evolutionary process and Gandy (2004) notes that interests in infrastructural investment are declining. The spatial distribution of this infrastructure has implications for social fragmentation and increased inequalities. Increased interest by the private sector in infrastructure investments further exacerbates these issues. As a result, Gandy (2004) reconsiders the notion of an urban metabolism indicating that it is not a homogenous and linear process which occurs throughout the entirety of the urban landscape particularly with regards to urban water resources.

Infrastructure

Urban infrastructure plays a fundamental role in cities which extends beyond the notion of the 'urban metabolism'. Jordan & Infante (2012) note that challenges faced by the contemporary city, call for solutions which are aimed at addressing social, environmental and economic issues. The way in which a city is planned, designed and built provides numerous challenges, but may also harness numerous solutions (Jordan & Infanta, 2012). These challenges and their associated solutions are often deeply ingrained in the infrastructure of which the city is comprised. Infrastructure thus provides a means through which to address numerous challenges which include the need for environmental sustainability, the addressing of numerous social issues, and economic growth and development, simultaneously and sustainably (Jordan & Infanta, 2012).

Jordan and Infante (2012) discuss the need for 'eco-efficiency' which is a concept in which environmental protection is promoted whilst simultaneously addressing social and economic issues. The concept "combines economic efficiency with ecological efficiency and essentially means creating

more goods and services with ever less use of resources while creating less waste and pollution”(Jordan & Infante, 2012:535). Jordan & Infante (2012) note that infrastructure plays a major role in facilitating the concept of ‘eco-efficiency’ as well as the notion of ‘social inclusiveness’. ‘Social inclusiveness’ refers to providing all those residing within an urban area with equal access to opportunities and resources so as to create a state of equality (Jordan & Infante, 2012). Jordan and Infante (2012) maintain that infrastructure, “affects economic competitiveness, social inclusiveness, quality of life and environmental health”(Jordan and Infante, 2012:536). Furthermore, it is noted that the effects and influence which infrastructure bears over a city can occur over numerous time-lines from immediate to long-term and its effects can be both indirect or direct (Jordan & Infante, 2012).

Infrastructure development is costly and requires a wide variety of resources thus development of any kind requires careful consideration and scrutiny. In addition, infrastructure is a long-term investment and has a lengthy life-span thus is highly influential over the way in which a city operates which can persist for decades (Jordan & Infante, 2012). These factors highlight the need for infrastructural investment which promotes long-term benefits for economic growth and development, society and the environment.

Todes (2012) recognises that strategic spatial planning should play a fundamental role in infrastructural development. This is in alignment with the ideas expressed by Jordan and Infante (2012) for a way in which to achieve infrastructure development which promotes long-term solutions which are both efficiency and effectiveness. United Nations (UN)-Habitat (2009) acknowledge the role of spatial planning and note its importance in overcoming various challenges, particularly within the developing countries. Mattingly (2001) argues that the spatial form of a city is shaped largely by physical infrastructure. In light of this, Mattingly (2001) notes, infrastructure development should be guided by, and intrinsically, linked to spatial planning. Spatial planning should thus guide the development of infrastructure so as to achieve the desired urban form and promote a more inclusive city (Brown & Lloyd-Jones, 2002).

Spatial Planning and Urban Design

Spatial planning and urban design can be used as a medium through which to promote the notion of the sustainable city. Creating a state of sustainable development and achieving sustainable cities can be achieved through manipulating urban metabolisms via appropriate design and spatial distribution of infrastructure.

Nilsson & Ryden (2012) note that, “Regional/spatial planning gives geographical expression to the economic, social, cultural and ecological policies of society. It is at the same time a scientific discipline, an administrative technique and a policy developed as an interdisciplinary and comprehensive

approach directed towards a balanced regional development and the physical organisation of space according to an overall strategy”(Nilsson & Ryden, 2012:205). It is also indicated that the term ‘spatial planning’, “includes all levels of land use planning, that is, urban and rural planning, regional planning, environmental planning, national spatial plans, and planning on international levels” (Nilsson & Ryden, 2012:205) thus it has influence at a variety of spatial scales.

Bahrainy & Bakhtiar (2016) indicate that there are numerous definitions of urban design within the literature and suggest that the lack of a dominant definition is indicative of the complex nature of all that urban design encapsulates. Bahrainy & Bakhtiar (2016) site a definition which maintains that, “urban design is concerned with the physical form of the public realm over a limited physical area of the city and that it therefore lies between the two well-established design scales of architecture, which is concerned with the physical form of the private realm of the individual building, and town and regional planning, which is concerned with the organisation of the public realm in its wider context”(Bahrainy & Bakhtiar ,2016:6). The Royal Institute of British Architects maintain that, “urban design is an integral part of the process of city and regional planning”(Bahrainy & Bakhtiar, 2016:6).

Spatial planning and urban design are processes through which sustainable development can be implemented and achieved (Nilsson & Ryden, 2012). Growing international awareness of, and pressures on, the need for sustainable development has created pressure upon spatial planners and urban designers to effectively design, provide and distribute the necessary infrastructure to enable people to promote sustainability through the way in which they live (Nilsson & Ryden, 2012). Nilsson & Ryden (2012) note that many international agendas and planning initiatives break down sustainable development into economic, social and environmental concerns and must balance these concerns in order to create a state of sustainable development.

Despite the need to focus on economic, social and environmental issues literature on sustainable spatial planning focuses predominantly on environmental sustainability and the impacts of the changes in land-use, infrastructure and developments on this environment (Naess, 2001). Naess (2001) notes that urban planning differs significantly between the global north and global south and so too does the notion of sustainable development. Urban planning in cities of the global south focuses predominantly on improving human health and liveability whilst in cities of the global north where living standards are high by comparison planning is focused on curbing the expenditure and use of natural resources (Naess, 2001). Naess (2001) argues that, “In order for the development of land use, patterns of built-up land and infrastructure in an area to be characterised as sustainable, it must secure that the inhabitants of the area can have their vital needs met in a way that can be sustained in the future, and is not in conflict with sustainable development at a global level”(Naess, 2001:505). Naess (2001) notes further that

there are numerous ways in which to achieve this through spatial planning initiatives. Spatial planning initiatives are faced with the challenge of balancing the use of natural resources with the promotion of economic and social growth and development and environmental sustainability that is sustainable in the long-term and is thus able to cater to the needs of future generations (Naess, 2001).

The Link Between of Spatial Planning, Urban Design, Urban Metabolisms and Infrastructure and the Creation of Sustainable Cities

As mentioned spatial planning and urban design are fundamental in the promotion of sustainable development and ultimately the realisation of the sustainable city. These disciplines must incorporate the notions of urban metabolisms and the evolving concepts of urban infrastructure into their approaches to promote sustainable cities.

The study of urban metabolisms can be used for a variety of practical applications which pertain to both urban design and spatial planning (Kennedy *et al*, 2011). Urban metabolisms have received increased interest by researchers and numerous studies have been conducted which provide valuable data which can be utilised to guide spatial planning and urban design. Kennedy *et al* (2011) note four major uses for these studies associated with urban metabolisms; 1) 'sustainability indicators', 2) 'GHG emissions', 3) 'mathematical models', and 4) 'design tools' (Kennedy *et al*, 2011).

The sustainability exhibited by an urban area can be calculated using a variety of 'sustainability indicators'. Kennedy *et al* (2011) note that these measurements are an integral component to reports compiled on the State of the Environment (SOE) and that information contained within urban metabolism studies. The studies have produced information pertaining to, "energy efficiency, material cycling, waste management, and infrastructure in urban systems"(Kennedy *et al*, 2011:4). Reporting on the SOE is important in decision making processes and serves as a vital prerequisite study for policy making and spatial planning. Studies conducted on urban metabolisms thus provide pertinent information for city planners when considering environmental factors within an urban area (Maclaren, 1996; Kennedy *et al*, 2011).

'GHG gas accounting' is a relatively recent practice which has come to the fore in light of the effect of GHG emissions on planetary systems, most notably, climate. In line with creating sustainable cities many urban areas are attempting to reduce overall GHG emissions in a bid to reduce the negative impacts of these areas on the natural environment. Studies on urban metabolisms aid in quantifying GHG emissions within a specific urban area and can be used to highlight areas where reductions are required. These GHG's are often emitted as waste from various processes which include electricity production and as a by-product of motor vehicles and include methane and carbon dioxide. Information

generated by urban metabolism studies can be used by planners to curb GHG emissions and promote sustainability.

A wide variety of tools designed to guide sustainable development have been developed as a product of metabolism studies. These tools are useful for a range of professions and follow four major design principles, “shapability, sustainability, reconstruction and responsibility”(Kennedy *et al*, 2011:6). The design approach, which is cognisant of the urban metabolism, then seeks to improve the quality of an urban area by focusing on, identification, diversity, flexibility, degree of self-sufficiency, and resource efficiency”(Kennedy *et al*, 2011:6). For example; systems which utilise greywater as a substitute for potable water in activities which do not require drinking water, i.e. watering of gardens and flushing of toilets, would be regarded as sustainable design initiatives and are often informed by urban metabolism studies (Kennedy *et al*, 2011).

Studies on urban metabolism can be used as a guide for spatial planning and urban design but spatial planning and urban design interventions can also be utilised to adjust and manipulate urban metabolisms. Urban design and spatial planning are inherently linked to the type, spatial distribution and form of urban infrastructure. The planning and design of green infrastructure within the city has become a major international focus.

Various studies, including that by Takano *et al* (2002) have provided evidence which links accessibility to green open spaces to the overall improvement of human health. Green infrastructure, also known as green-blue infrastructure (blue referring to elements pertaining to water) has been shown to improve both human and ecosystem health where human health is defined as, “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”(World Health Organisation (WHO), 1948), and ecological health as, “one that is free from distress and degradation, maintains its organisation and autonomy over time and is resilient to stress”(Tzoulas *et al*, 2007:3). Tzoulas *et al* (2007) suggest that an interdisciplinary approach to land-use planning is required to address concerns of human and ecological health and should include factors which address social, environmental and economic concerns.

As indicated infrastructure is utilised by spatial planners and urban designers as a means through which to manipulate urban metabolisms and achieve sustainable development. Sandstrom (2002) indicates that the ideology of green infrastructure has been identified as a means through which to incorporate planning with urban green spaces. Green infrastructure, “can be considered to comprise of all natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales”(Tzoulas *et al*, 2007:6). This infrastructure promotes a greater quality along with an increased quantity of urban green spaces according to Rudlin and Falk (1999) and, as

noted by Walmsley (2006), can be used as a means to guide future development of an urban area if it is appropriately planned (Tzoulas *et al*, 2007). Tzoulas *et al* (2007) provide a wide range of evidence which supports the notion that well planned green infrastructure can be used as a means to promote both human and ecosystem health as well as to guide the future development of a city. Pugh *et al* (2012) indicate that green infrastructure can play a fundamental role in improving air quality within urban areas providing greater evidence to support the fact that this infrastructure contributes to human and ecosystem health.

Gill *et al* (2007) & Foster *et al* (2011) claim that green infrastructure has a major role to play in generating a means of resilience and adaptation for urban areas in response to climate change. It is indicated that attention on curbing the negative effects of climate is focused largely on reducing the emission of GHG's, however Gill *et al* (2007) suggest that planning has a major role to play in providing measures to promote adaption and resilience within cities. It is further noted that infrastructure in itself contributes to increased vulnerability to climate change within urban areas. Infrastructure changes the characteristics of surfaces often decreasing albedo resulting in increased temperatures within urban areas ultimately causing a condition referred to as the urban heat island (Gill *et al*, 2007). This changes the thermal properties of the city in relation to surrounding areas and results in shifts in local climatic conditions. In addition, the reduction of vegetated land results in reduced porosity of surfaces thus increasing surface runoff during high rainfall events. These factors result in increased vulnerability of the urban population to the negative impacts of climate change. Green Infrastructure in this study is found to moderate the negative impacts of climate change and is thus viewed as a necessary addition to urban planning (Gill *et al*, 2007).

Spatial planning and urban design thus play a vital role in the promotion of a sustainable city. Rana (2009) notes that urban planning must take into account environmental problems within the city which they split into two focus areas. The first focus area pertains to 'environmental health' and includes solid, dissolvable and airborne pollutants and the liveability of an area largely linked to the level of sanitation (Rana, 2009). These impacts have an immediate impact on local communities and must be addressed in an urgent manner. The second focus area is centered around environmental issues which pose a threat to the to the long-term sustainability of a city, these include increasing accumulation of solid waste, climate change and the mismanagement and resultant degradation of natural resources (Rana, 2009). Rana (2009) indicates that a major issue arose when cities of the global south began to adopt the notion of a sustainable city into their planning agendas and made the first focus area a priority neglecting long-term environmental threats.

Spatial planning for the sustainable city can also be utilised as a way in which to promote environmental justice which, “exists when environmental pollution and environmental benefits are distributed equally among the societies”(Rana, 2009:514). Rana (2009) notes that concerns of environmental justice are particularly pertinent given the high rates of socio-economic inequality which often persist within cities of the global south. The urban poor must be considered in spatial planning approaches to promote a sustainable city as these people are often both responsible for environmental degradation and, conversely, are the most impacted upon by this resultant degradation (Rana, 2009). Thus spatial planning must endeavour to provide economic opportunities for these people to reduce negative environmental impacts. Spatial planning must endeavour to promote equal socio-economic opportunities to all and ensure that the urban elite do not monopolise access to environmental resources (Rana, 2009). Rana (2009) also notes that the inequitable access to natural resources which favours the urban elite, who are also largely responsible for environmental degradation, has resulted in the need for spatial planning initiatives to reduce the negative environmental impacts by this group and redistribute resources in an equitable manner.

The Spatial Planning Paradox

Campbell (1996) highlights the conflicts that exist between the various spatial planning goals of social, economic and environmental sustainability. The growth of cities has historically been characterised by the destruction of the natural environment however environmental considerations in planning have not always been overlooked as the current urgency surrounding environmental protection might suggest (Campbell, 1996). Campbell (1996) indicates that numerous spheres of spatial planning have taken the natural environment into account for example, planning for open space and urban parks. Planners must however take two additional priorities into consideration, that of economic growth and development and social development (Campbell, 1996). Campbell (1996) notes that despite many planners portraying themselves as pro equality and fighting for social justice their actions may suggest otherwise. This is often exemplified in high-income developments and strategies for economic growth and development. Planning is thus faced with the mammoth task of promoting economic growth and development, promoting social equality and justice and, in so doing, preventing environmental degradation (Campbell, 1996). Planners must seek to balance these three priorities and incorporate these concerns into spatial planning initiatives in order to achieve a state of sustainable development. The diagram below illustrates the conflicts between these three major priorities.

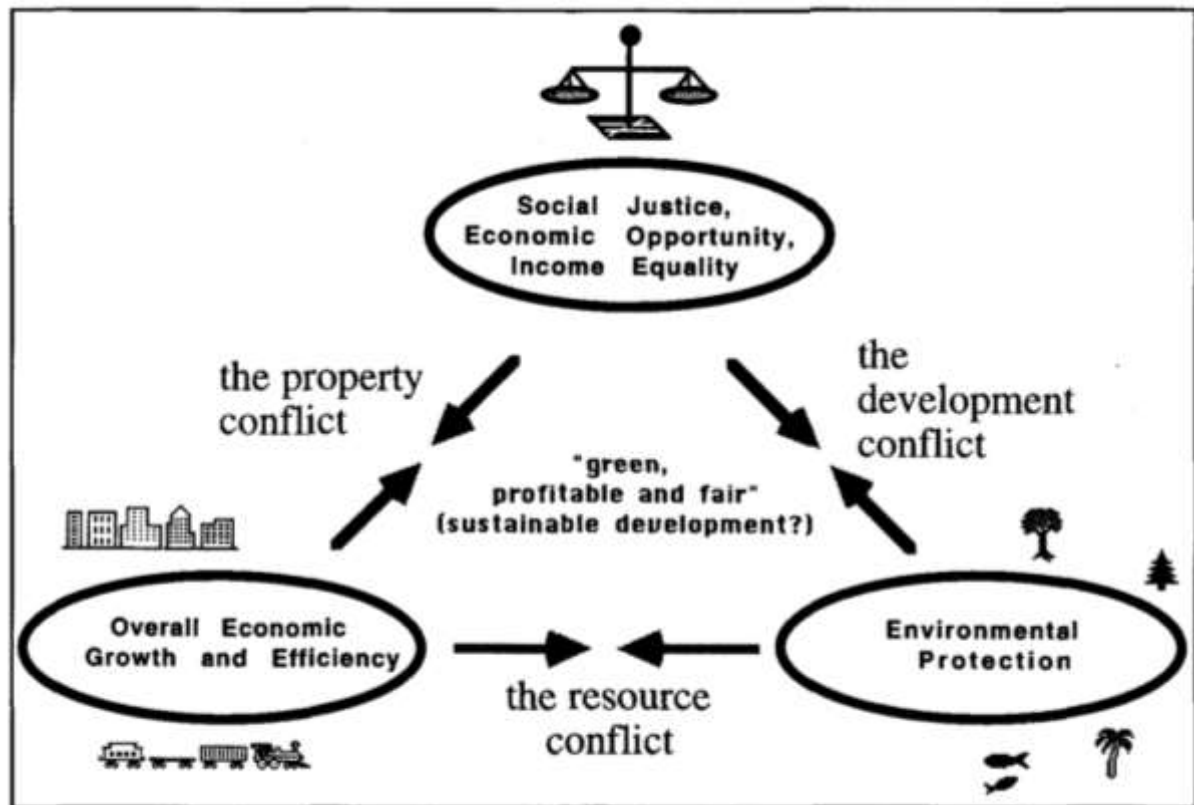


Figure 3: Diagrammatic Representation of the Conflicts Between the Three Priority Areas of Spatial Planning (Campbell, 1996:298)

Nilsson & Ryden (2012) suggest that planning for sustainable development is made difficult by ambiguities between the various definitions within the literature of this form of development. These ambiguities result in numerous interpretations of this concept and thus spatial planning, and the initiatives and interventions therein, are in essence responsible for providing a definition for sustainable development in a given context (Nilsson & Ryden, 2012). This results in the contestation of these definitions within the field of planning (Nilsson & Ryden, 2012). In addition, the value systems of a government's planning approach and that of individual planners' have significant influence over the way in which sustainable development is approached. Nilsson & Ryden (2012) suggest that despite the differences in spatial planning and urban design approaches which are utilised to achieve sustainable development, the fundamental outcomes of balancing the need of bettering local communities and society at large, protecting the natural environment and promoting economic growth and development in a manner which sustains generations to come, persist.

Rana (2009) notes that a major conflict exists between the need for environmental justice, the equitable distribution of resources and the notion of the sustainable city. It is argued that the redistribution of environmental resources away from the urban elite to the urban poor cannot be

achieved under the current 'neoliberal market economy' in which all are unable to participate in an equitable manner (Rana, 2009). This is intensified in cities of the global south given the large gap that exists between the urban rich and the urban poor. These concerns must be taken into consideration by spatial planning initiatives and ways in which to promote equality must be found under current economic conditions to create a truly sustainable city.

Conclusion on Literature

The literature, although unclear on a universally accepted definition for sustainable development and the sustainable city, is predominantly focused on creating cities which demonstrate resilience through adaptability to short and long-term change. There are gaps in the literature pertaining to the provision of guidance for cities of the global south in achieving sustainable outcomes. The literature focuses predominantly on systemic transitions as a means to reduce GHG emissions within urban areas. There is little discussion around transitions in urban water management approaches and a discourse for action, particularly for developing countries, in effecting such transitions. It is clear that infrastructure plays a major role in manipulating and regulating urban metabolisms however designing appropriate infrastructure to target sustainable outcomes is insufficient. Stringent legislation, policies and institutional arrangements along with extensive resources are required as a prerequisite to the installation of appropriate infrastructure. Spatial planning is recognised as a tool through which to implement policy and promote the equitable distribution of resources. The literature focuses little on this profession as a means through which to transform urban systems in cases where change is urgently required and where the current policy and institutional frameworks at a municipal level are incapable of bringing about this necessary change.

This dissertation aims to address a number of these knowledge gaps by attempting to answer the above stated research questions through a series of defined objectives. This literature review has provided valuable insight into a number of schools of thought and existing knowledge relevant to the topics investigated throughout this dissertation. The information gathered within the review of existing literature informs this research throughout.

Chapter 3: Water Sensitive Urban Design

Introduction

This section aims to provide an overview of WSUD by considering the framework, objectives and principles of the approach to gain an enhanced understanding. The section considers the application of this management approach in Australia and reviews two case studies detailing the benefits of implementing this approach. The review also considers the role of spatial planning within the WSUD framework.

Water Sensitive Urban Design: Overview

WSUD can be defined "as the integration of urban water cycle management with spatial planning, which considers all parts of the urban water cycle"(Rohr, 2012:64). WSUD is an urban water management strategy which promotes sustainability limiting impacts on the natural environment and ensuring the protection of hydrological flows and processes (Wong & Eadie, 2000). The strategy is characterised by three major objectives; 1) ensure the protection of natural hydrological processes, 2) increase resilience of communities to the negative impacts of flooding, and 3) improve the quantity and quality of urban water resources (Melbourne Water, 2002).

WSUD is a concept which requires interdisciplinary input to formulate and implement a plan designed to guide urban development in such a way which promotes the achievement of multiple objectives (Wong & Eadie, 2000). In addition, the concept exemplifies a holistic approach which incorporates professions including urban design, spatial planning, stormwater management and landscape architecture and the infrastructure associated with these professions (Wong & Eadie, 2000).

WSUD integrates spatial planning and design as integral components responsible for the management of the urban water cycle (Kunapo *et al*, 2009). WSUD focusses on all aspects of the urban water cycle promoting sustainable development within urban areas with a major focus on the management of stormwater and the recognition of this water as a valuable resource, one which must be managed in an effective manner to ensure the protection of aquatic ecosystems within, and downstream, of an urban area. The approach informs project planning and places a strong emphasis on cost reduction in both drainage networks and the treatment of water (Kunapo *et al*, 2009). The strategy incorporates 'best planning practices' (BPP's) and 'best management practices' (BMP's) to promote sustainable development and the water sensitive city.

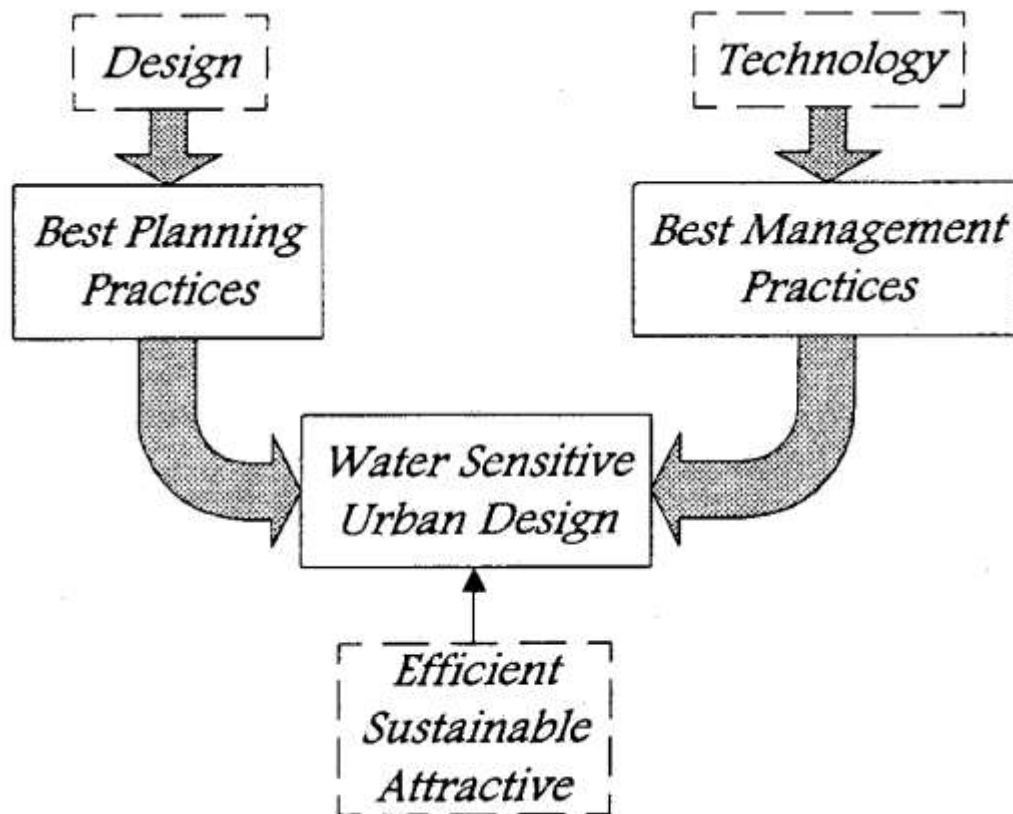


Figure 4: Flow Diagram Indicating the Relationship Between BPP's and BMP's within WSUD (Wong & Eadie, 2000:6)

Sustainable Urban Drainage Systems (SuDS) provide an alternative stormwater management approach which promotes sustainable development and is an example of a WSUD approach which incorporates BPPs and BMPs. This approach to the management of surface water accrued as runoff during storm events, incorporates a drainage pattern which is designed to mimic that of natural processes and often takes the form of a network of interlinked systems commonly referred to as a 'treatment train'. This approach aims to achieve a number of objectives which seek to promote a high level of quality and quantity of stormwater runoff thereby supporting biodiversity and recognising the value of this resource (Armitage *et al*, 2014). Urbanisation has a profound impact on the water cycle which includes reduced rates of infiltration, changes in the volume and flow patterns of runoff, and modification of natural drainage systems thus an approach to stormwater management is required adapt to and address the changing characteristics of urban areas.

WSUD Australia

Originating in Australia, this holistic approach has its roots in stormwater management from which it evolved to provide an alternative to the way in which urban water resources are managed (Wong, 2006). The management of these urban water resources and systems required an approach whereby

professionals from a multitude of fields worked together in an interdisciplinary manner in order to achieve a common set of objectives (Wong, 2006). A case study produced by Coombes *et al* (2000) which involved the monitoring of WSUD in a new development in Newcastle, New South Wales, Australia, found that the management system recorded water savings in excess of 60% and retained nearly all stormwater runoff generated in the development.

Urban development can have significant impacts on the local water cycle and poses a substantial threat to water quality and quantity. Coastal water, waterways and indeed entire catchments are at risk of development, thus it is imperative that development initiatives be cognisant of their environmental impacts by promoting sustainability (Wong, 2006).

There are two key objectives in ensuring the sustainable management of water resources in urban areas: environmental sustainability and environmental protection of areas from which water is diverted and collected for the consumption of urban residents, and to ensure that this water is treated to an acceptable quality which does not jeopardise the environment into which it is discharged (Wong, 2006).

Urban development has been shown to have numerous detrimental effects upon urban water systems. In order to negate these negative impacts an integrated, interdisciplinary approach is required to manage urban water resources (Wong, 2006). WSUD has, in recent years, been hailed as an approach which can ensure that urban developments are water sensitive and promote sustainable development through the incorporation of economic, social and environmental concerns. Sustainable development, as defined within the context of WSUD, is development which ensures that "lifestyles, and their supporting infrastructure, can endure indefinitely because they are neither depleting resources nor degrading environmental quality"(Wong, 2006:2).

WSUD Principles and Framework

A broad framework for this systems based approach was formulated to incorporate various systems which include the water cycle and the surrounding landscape and, most pertinent within urban areas, the built form.

In order to achieve the main goals set out as obtainable, through WSUD, four principles were set out for the purpose of acting as guidelines. These are summarised below.

1. Decreasing water demand through alternative means of harnessing and storing water i.e. rainwater and the promotion of 'water efficient appliances' (Wong, 2006).

2. Reducing volumes of wastewater and ensuring that all wastewater that is treated is at a standard which is deemed acceptable for either the re-use of this effluent or the safe release thereof into natural water systems (Wong, 2006).

3. The treatment of urban stormwater to a water quality suitable for either re-use or discharged into natural water systems (Wong, 2006).

4. Harnessing stormwater and making use of this resource as a means to enhance recreational areas and the aesthetics of developments (Wong, 2006).

There are four major elements regarded as essential to the successful implementation of WSUD within Australia. These are; 1) regulatory framework, 2) assessment and costing, 3) technology and design, and 4) community acceptance and governance (Wong, 2006).

1) Regulatory Framework

This element indicates the need for all tiers of government to promote the successful implementation of WSUD in the development of urban areas. A holistic and interdisciplinary approach to the water cycle within catchments is required. Catchment management approaches should incorporate all systems and actions that have an impact on the water cycle and manage these at various levels throughout the catchment (Wong, 2006).

2) Assessment and Costing

This element relates to the cost versus benefit of WSUD and the amount of time it would take to see these benefits. The benefits of this approach can only be seen through continuous assessment and monitoring (Wong, 2006).

3) Technology and Design

This requires a multidisciplinary approach in creating new means and initiatives to promote WSUD. Constant innovation is required to enhance the application of WSUD.

4) Community Acceptance and Governance

The acceptance and buy-in of this approach by local communities is essential in creating political will in the implementation of WSUD. Community engagement initiatives which seek to understand the attitudes of local residents to water quality and re-use have been utilised to help inform the creation of WSUD strategies and the development of associated policies. The success of these initiatives rests largely in community buy-in and so workshops and engagement initiatives are highly beneficial ways of generating capacity and knowledge within the local community (Wong, 2006).

The management of urban water resources requires an integrated approach to development. The increased potential for innovation through interdisciplinary work is seen as a major advantage of the WSUD approach and the incorporation of urban design and spatial planning with the management of the urban water cycle drastically increases the chances of successful implementation. WSUD operates at a variety of spatial scales from household to precinct to an entire catchment. Perhaps most important here is the recognition that, "the principles of WSUD are equally relevant to achieving sustainable developments in other places with different water infrastructure systems to the Australian context"(Wong, 2006:8).

WSUD and Spatial Planning

WSUD incorporates the management of water resources into approaches which focus on spatial planning (Rohr, 2012). Furthermore, it integrates all aspects of the urban water cycle into spatial planning including the management of storm water, the supply of water for various uses and the treatment of wastewater (Rohr, 2012). It is essential that these factors are taken into consideration during the early stages of the spatial planning process so as to promote environmental, social, economic and cultural sustainability (Rohr, 2012). In addition, the inclusion of WSUD into urban planning can further promote interdisciplinary action creating cohesion between different professions and increasing interactions between various stakeholders. This enhanced approach will create conditions which are conducive to achieving sustainability. Sustainable development can thus be promoted and enhanced in this manner.

It is imperative that a wide range of stakeholders be included so as to successfully incorporate WSUD into urban development. These stakeholders include; local community members, local municipalities, engineers, private and commercial developers, various governmental departments, economists, homeowners, building contractors, architects, storm water management agencies and a host of other groups and individuals (Rohr, 2012). Strategies which seek to incorporate water management into the spatial planning process are devised from the collaboration of all these stakeholders. These strategies usually emphasise two major objectives focussed largely on; 1) the conservation of water resources, and 2) the management of stormwater (Rohr, 2012).

Spatial planning interventions to promote the conservation of water resources include the installation of permeable surfaces, the use of water tanks to capture rainwater, the use of efficient irrigation systems which reduce wastage and the direction of reusable water to areas where it is of best and safest use i.e. garden beds (Rohr, 2012).

Interventions to manage stormwater include designing a means to store water either above or below ground and ensure that this water is of a quality that is not harmful to the environment. Infrastructure plays a major role in the management of stormwater and may include bioretention ponds, artificial wetlands, sand filters and infiltration systems (Rohr, 2012). Other interventions are aimed to control source pollutants and seek to reduce the use of harmful substances such as pesticides. Spatial planning must ensure that this infrastructure is equitably distributed and that its spatial orientation promotes effectiveness and efficiency to meet the requirements of sustainable development.

Water is an extremely important factor to take into account within spatial planning and urban design. Water has the ability to sustain, enhance and retain cultural and natural diversity, promote human health and well-being and enhance economic growth and development. It is a resource which is able to significantly enhance an urban area, through the facilitation of spatial planning and urban design by enabling the creation of high quality urban spaces (Rohr, 2012). Spatial planning provides a mechanism through which both spatial and water related issues can be dealt with in a holistic manner (Rohr, 2012). The integration of spatial issues and water management is essential in promoting sustainable urban environments and creating water sensitive cities.

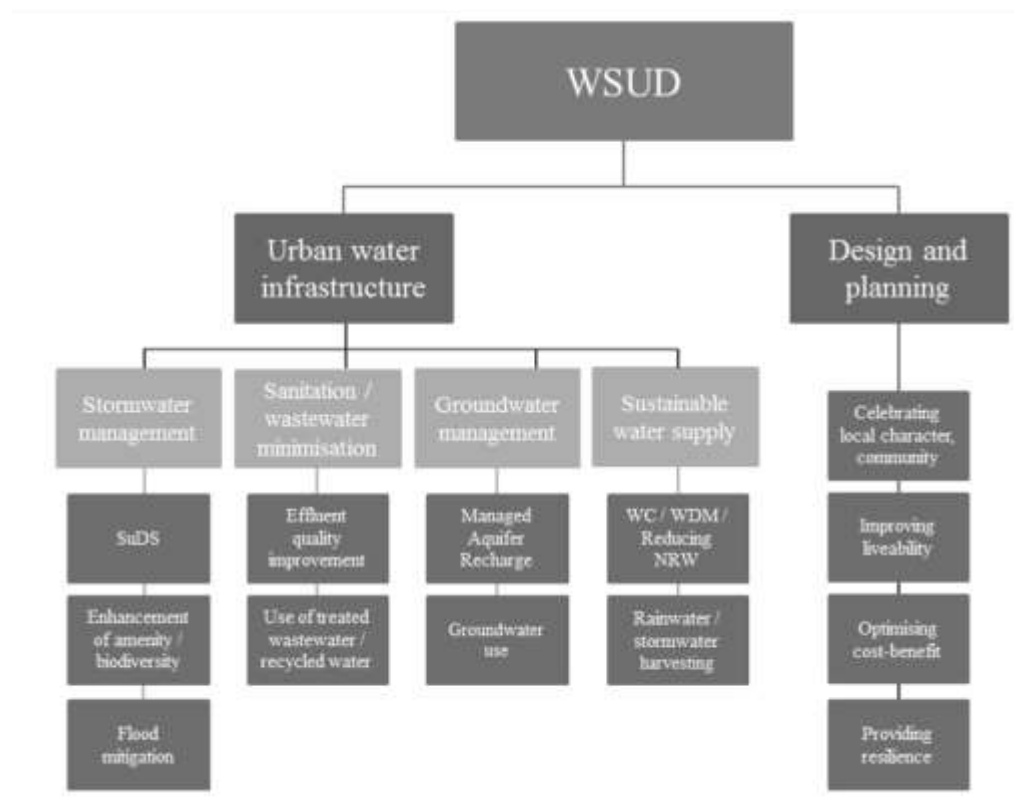


Figure 5: Infrastructure and Design and Planning Functions within WSUD (Armitage et al, 2014:46)

Case Study 1: Figtree Place

A case study was conducted on Figtree Place, a development in Newcastle, New South Wales, Australia (Coombes *et al*, 2000). The development is regarded as water sensitive and incorporated economic growth and development with concerns for the natural environment in a manner which promotes the concept of sustainable development. The development recognises the ability of WSUD to provide solutions at a local level to the greater, global, challenges such as curbing global climate change and creating both global and local resilience in response to this change (Coombes *et al*, 2000).

The development of Figtree Place consisted of a total of 27 individual housing units. The site was formerly used as a major transport hub and had become contaminated with various pollutants as a result of hydrocarbon spillage (Coombes *et al*, 2000). Despite these contaminants the groundwater below the site was of a quality suitable for irrigation purposes. Furthermore, with the development of infrastructure designed to retain stormwater and provide soakaway zones, enabled the management of these pollutants removing them from them from the surface and into the aquifer at undetectable levels (Coombes *et al*, 2000).

Proposals were made to retain stormwater to be used for domestic purposes such as sanitation and irrigation, it was however deemed too higher risk to human health for this water to be utilised as a potable water resource. The study indicated that, despite the use of this stormwater for domestic purposes and allowing the necessary quantities to fulfil natural demands such as groundwater recharge, there would be an excess in supply from the retention infrastructure (Coombes *et al*, 2000). The excess water was made available for bus washing services at the nearby bus station. The water resources retained within stormwater retention infrastructure on the site provide water resources to meet the full on-site demand for irrigation and off-site bus washing and half of the demand required for the flushing of toilets (Coombes *et al*, 2000). In addition, the retention of stormwater reduced the risk of downstream flooding, reduced the quantity of pollutants entering natural water ways and reduced pressures on existing stormwater infrastructure (Coombes *et al*, 2000).

The infrastructure utilised to promote a water sensitive development included rainwater tanks below ground level, trenches adjacent to houses to manage overflow from rainwater tanks, a stormwater retention basin and a borehole for groundwater use (Coombes *et al*, 2000). The surfaces are largely impermeable and drainage systems deliver stormwater to the retention basin which is designed to remove contaminants and steadily recharge groundwater, the gravel trenches provide a similar function form the overflow of rainwater tanks (Coombes *et al*, 2000). In this manner stormwater is retained on-site to meet environmental requirements and serve as a water resource for local residents.

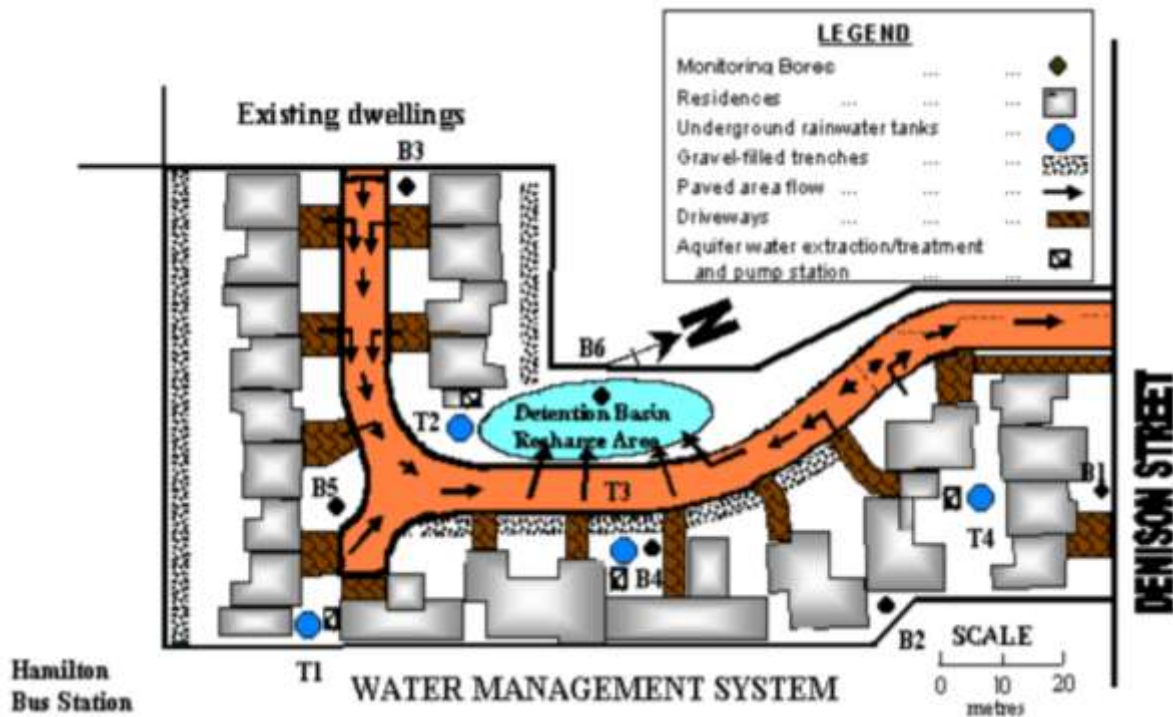


Figure 6: Plan Depicting WSUD Infrastructure Utilised at Figtree Place (Coombes et al, 2000:5)

Monitoring has indicated numerous benefits as a result of the successful implementation of WSUD principles and infrastructure within this local development. The first set of results however did not indicate success with regard to the quality of water captured within the rainwater tanks. It was found that this was largely due to negligent installation which allowed tanks to become contaminated however, after this was rectified and the tanks were more closely monitored and managed the water quality improved significantly (Coombes *et al*, 2000).

The study showed that Figtree Place, subsequent to the implementation of WSUD principles and infrastructure, recorded a reduction in its reliance on municipal water supply by 65% and projects a saving of 45% over the long-term (Coombes *et al*, 2000). The social acceptance of these principles was extremely high recording 95% support for the storage and re-use of stormwater however acceptance for the this water as a possible potable water source received only 70% acceptance (Coombes *et al*, 2000). Benefits accrued from the spatial layout of the development include enhanced security and a greater sense of community (Coombes *et al*, 2000). In addition, the development recorded cost savings in both the construction and municipal services (Coombes *et al*, 2000).

Figtree Place provides a good example of the benefits of incorporating the principles of WSUD into local level spatial planning and urban design as a means of promoting sustainable development and contributing toward a water sensitive city.

Case Study 2: Grove Precinct

A case study of the Grove Precinct, Perth, Australia, provides an additional example of the effectiveness of WSUD. The precinct installed an 'integrated water management system' which comprises infrastructure to facilitate the collection of rainwater, the re-use of wastewater and the collection, and treatment, of stormwater (Armitage *et al.* 2014). All the goals associated with WSUD are achieved through the holistic management of the urban water cycle within this development (Armitage *et al.* 2014).

A wastewater treatment (WWT) system treats both grey and black water which is reused for irrigation purposes, saving approximately 700 kilolitres per annum (kl/pa) (Armitage *et al.* 2014). The on-site harvesting of rainwater meets all the potable water needs within the precinct and has significantly reduced demand for potable water supply by municipal systems (Armitage *et al.* 2014). Rainwater tanks are supplied predominantly by rooftops capture water during rainfall events. The water is then pumped to a separate facility where it is treated using a combination of UV technology and microfilters (Armitage *et al.* 2014). The treated water is then available for potable use and is supplied via an internal piped network. The rainwater collection, transport, treatment and delivery is low maintenance given the innovative use of meters as monitoring systems and syphons to create pressure (Armitage *et al.* 2014). The total potable water saved by this system per annum is approximately 730 kl (Armitage *et al.* 2014).

SuDS are utilised to manage stormwater within the precinct. The precinct receives large amounts of stormwater given its low-lying position within the catchment. The stormwater system is designed to cope with large storm events, in severe cases the system is designed to remove excess water from the site delivering it to off-site stormwater infrastructure (Armitage *et al.* 2014). Stormwater runoff is treated on site, improving the water quality by removing vast quantities of both solid and dissolvable pollutants (Armitage *et al.* 2014). A large holding tank and a series of sedge beds are responsible for capturing and cleaning this water, after which it is delivered to an on-site basin which facilitates its infiltration into the aquifer (Armitage *et al.* 2014).

The concept of WSUD was fully endorsed and promoted by the developers of the Grove Precinct. Numerous educational programmes are held within this precinct as a means of creating awareness in surrounding communities as to the numerous benefits which WSUD provides (Armitage *et al.* 2014).

Conclusion

WSUD has recorded high success rates at both a local and precinct scale within Australia and has proven to be a highly effective spatial planning, urban design and urban water management approach. Its promotion of water sensitive infrastructure has recorded large water savings reducing pressures of water demand from municipal services thus reducing pressures on off-site infrastructure. The principles of WSUD take into account environmental, economic and social issues in promoting sustainable development practices. The incorporation of water concerns into spatial planning, urban design and urban water management at a multitude of scales can thus have positive outcomes for economic growth and development, social equality and justice and environmental protection.

WSUD has been highly effective in the global north but how applicable it is to the global south and if it can be used in these cities as a means to promote sustainable development and achieve water sensitive cities, remains questionable. It is likely that adjustments will have to be made to accommodate the specific conditions which characterise the global south cities within South Africa. The implementation of WSUD clearly requires strong policy, institutional arrangements and effective governance. The flexible nature of WSUD to operate at a multitude of scales, it is argued, makes it a viable water management option to achieve sustainable development goals in South Africa. To adequately implement WSUD in South African urban areas a review of the country's current development objectives and water policy as well as urban management strategies will be required to identify current issues. In addition, this review may highlight ways in which WSUD can be successfully implemented in the context of a global south city within South Africa.

Chapter 4: National Water Management, South Africa

Introduction

South Africa is a water scarce country currently facing numerous challenges with regard to the management of its water resources (DWA, 2013a). These challenges include concern over the state and quality of fresh water resources, the quantity of this resource and the state of and pressures on the natural environment (Roux *et al*, 2014; DWA, 2013a). These pressures and challenges are exacerbated by a rapidly growing population and the impacts of climate change. Legislation, policies, institutions and infrastructure are required to promote effective water management at a national, provincial and local scale in response to these challenges. “Water resources require careful management to enable the provision of basic water services to every citizen, while meeting the needs of economic growth without threatening the environmental integrity of water resources”(DWA, 2013a:7). This sections aims to provide an overview of national water policy in South Africa considering how this policy links to development planning and the informants it provides for urban water resource management.

Department of Water Affairs

The South African national Department of Water Affairs (DWA) is responsible for the regulation and monitoring of all water consumed within the domestic sector which includes the supply of water and all sanitation functions (DWA, 2013b). The department generates national water policies which uphold national legislation and target national development objectives. The policies generated by the DWA are major informants for urban water management strategies, these policies and the legislation with which they align are reviewed below as a means to consider national implications for urban water management.

National Development Plan

The National Development Plan (NPD) has developed a vision for South Africa to be achieved by 2030 which promotes growth and development within the country to be inclusive in nature, focusing on diversifying the national economy and promoting greater economic participation by the country’s citizens (Republic of South Africa (RSA), 2011a). Water plays a fundamental role in all economic sectors and the equitable allocation of this resource, appropriate development and measures to ensure its protection are vital to realising this vision (DWA, 2013a). These aspects of water resource management are central to achieving economic growth which promotes inclusivity, alleviating poverty in South Africa, and promoting equality in order to provide equal opportunity for all (DWA, 2013a). Targeting inequalities that exist throughout the country is essential in addressing issues which resulted from a system of institutionalised racial segregation. The effective management of water resources thus plays a fundamental role in increasing resilience among the citizens of South Africa contributing to the

improvement of various economic, social and environmental conditions. This will create conditions which will enhance human health and well-being through equitable access to resources and the sustainable management and use of those resources (RSA, 2011a).

Water legislation and Policy

National Water Policy

Water policy within South Africa required review and amendment so as to align itself with the 1996 South African Constitution following the abolishment of Apartheid governance (DWA, 1997). The National Water Policy White Paper for South Africa was incepted stating that, “the objective of managing the quantity, quality, and reliability of the nation’s water resources is to achieve optimum, long-term, environmentally sustainable social and economic benefit for society from their use”(DWA, 2013a:7). The policy indicates that the National Government of South Africa is responsible for all of the country’s water resources and, as acting custodian, manages these resources as a public trust. This water resource is defined as the sum of all water in the water cycle in its entirety within the country, this includes surface and groundwater resources and any and all movement between the various components of the water system (DWA, 1997).

The National Water Policy (NWP) requires the determination of an ecological reserve (ER) as a means to promote environmental sustainability. The ER is calculated as the volume of water required within natural systems to promote the integrity and natural functioning of that system. The NWP requires the water management initiatives to be divided into catchment management areas (CMAs) which are geographically defined by watersheds (DWA, 1997). Within these CMAs catchment management agencies are to be established under the authority of the national government. This has implications for urban water management as cities fall within an individual catchment and therefore the management of water resources in these areas is governed at the regional scale by a catchment management agency (DWA, 1997).

Water policy in South Africa is centered around the notion of sustainable development and is thus aligned with international goals (DWA, 1997). The current national policy approach to planning infrastructure and water use indicates that a, “multiple water use approach, which incorporates all water uses in an area including water supply, must be adopted in the planning of bulk infrastructure. This approach will also have equity and transformation as a priority”(DWA, 2013b:12). In addition, the policy requires a participatory approach to be taken whereby all stakeholders are included in the decision making processes to ensure that all water uses in a given area are accounted for (DWA, 2013b). The DWA (2013b) notes that the current challenge with regard to the provision of bulk infrastructure is that past planning practices have focused on the needs of a specific sector resulting in the exclusion of numerous water users. The 2003 Strategic Framework for Water Services has countered this issue

by mandating the integration of planning and all water related institutions to promote the effective planning of all water resources and associated infrastructure (DWA, 2013b). The DWA (2013b) promotes an, “integrated water resources management approach which promotes coordinated planning, development and management of water, land and related resources should be adopted in order to maximise equitable social and economic benefits”(DWA, 2013b:12).

National Water Resource Strategy

The National Water Resource Strategy 2 (NWRS 2) is the successor to the NWRS. The NWRS 2 is thus an amended version of the NWRS which was required to realign water strategies with a multitude of national interests and objectives. The vision put forth by the NWRS 2 is aligned with that of South Africa’s development vision for 2030 and is “centered on the notion of sustainable, equitable and secure water for a better life and environment”(Armitage *et al*, 2014:31).

The NWRS 2 combines water management goals with those of transformation and sustainable development (DWA, 2013b). The framework initiated the synthesis of the Water Services Act (WSA) and the National Water Act (NWA) into a single piece of legislation (DWA, 2013b). The combining of these two legislative documents has various implications for many water related policies (DWA, 2013b). Policy associated with the ‘water value chain’ (the removal of water from a water resource, the use of this water resource for productive and consumptive purposes and the subsequent return of this water back into the collective water resource) required amendment to include economic, environmental and social concerns within the entire ‘value chain’.

The NWRS 2 seeks to, “analyse[s] the role of water in the economy and identify[s] the specific challenges, development opportunities and actions that inform an agreed framework for priority areas of focus for the country”(DWA, 2013a:3). The strategy thus endeavors to guide growth and development in South Africa in such a way which promotes the NDP’s vision 2030 (DWA, 2013a). The National Planning Commission (NPC) has aligned itself to achieve this same vision and in so doing has made water a major focus through which to promote economic development and increase employment rates. It plans to achieve this through increased investment in the development and management of infrastructure designed to target the conservation of water resources, improve water demand management, improve WWT and increase water resource allocation to the economic sector (RSA, 2011a; DWA, 2013a). In addition, the NPC has targeted infrastructure investment through increased maintenance and upgrading of existing infrastructure, increase in resource allocation for the supply of bulk infrastructure and the provision of greater levels of support to those marginalised under Apartheid (DWA, 2013a). The NPC recognises the effective management of water resources within South Africa as pertinent to achieving the goals and objectives set forth within the 2030 vision.

The NWRS 2 maintains that water services and resource planning must promote the development of urban areas in such a way that is devoid of any and all racial and gender discrimination, promote both socio-economic and spatial integration, provide equal opportunities for all, promote democratic governance and the sustainable goals of the country (DWA, 2013a).). In addition, planning should promote public participation processes and provide adequate infrastructure which exhibits equitable spatial distribution (DWA, 2013a). Multiple use planning is promoted to enhance water management in a manner which ensures that the needs of all water users are accounted for in a specific area (DWA, 2013a). The Social Assessment and Development Framework established by the DWA guides water infrastructure planning to incorporate elements of multiple uses to address social needs more effectively and efficiently (DWA, 2013a). The DWA (2013a) notes that a new approach is required for the planning of water supply for communities and indicate that a range of different sources may have to be relied upon.

The NWRS 2 makes note of the high costs associated with infrastructure development and maintenance and calls for cost effective infrastructure which is sustainable over the long-term and does not require costly maintenance so as to relieve financial pressures on national, provincial and local government institutions (DWA, 2013a).

Water Supply and Sanitation

The provision of water and sanitation services in South Africa is governed by national legislation which, as mentioned, is a single document combining the legislation of the NWA and the WSA. This legislation guides the Water Supply and Sanitation Policy (WSSP) which highlights the need to integrate the notion of increased equality within South Africa with regard to the provision and access of water resources (DWA, 1994). The major principles of this policy are: “1) Development should be demand driven and community based, 2) Basic services are a human right, 3) ‘some for all’, rather than ‘all for some’, 4) Equitable regional allocation of development resources, 5) Water has economic value, 6) The user pays, 7) Integrated development, and 8) Environmental integrity”(DWA, 1994:8).

The policy defines the roles and responsibilities of local government in water supply and sanitation service provision indicating that local governments must adhere to the South African Constitution and promote sustainability through water and sanitation service provision (DWA, 1994). Local municipalities thus bear the bulk of the responsibility with regard to supplying citizens in their local area with adequate access to potable water and sanitation. The private sector plays a major role in both capital investment and the operating and continual maintenance of water supply and sanitation infrastructure (DWA, 1994).

Stormwater

Water services development plans (WSDP) are required, as mandated by the National WSA, to be developed by local municipalities which are responsible for stormwater management (Armitage *et al*, 2014). The National WSA mandates these WSDPs to include issues and concerns surrounding the management of stormwater resources so as to ensure that all of the urban water cycle is managed in a holistic and integrated manner (Armitage *et al*, 2014).

The citizens of South Africa are guaranteed the right, “to an environment that is not harmful to their health or wellbeing”(Armitage *et al*, 2014:37) by the National Environmental Management Act (NEMA) and the Constitution. Developers, as mandated by NEMA, are responsible for preventing any activity resulting in the harm of the natural environment, this, in terms of the NWA, includes water pollution (Armitage *et al*, 2014).

Groundwater

Groundwater resources within South Africa are regulated by both the NWP and NWA (Armitage *et al*, 2014). In addition, NEMA contains legislature pertaining to this resource and so too does the Minerals and Petroleum Resources Act (Act 28 of 2002) which protects this resource against the adverse effects of mining. Groundwater is recognised as an economic, social and environmental resource within the NWA and NWP. The NWP contains comprehensive policy guidelines for the use, abstraction, allocation, protection, management, monitoring and responsible institutions of this resource (Armitage *et al*, 2014).

Natural Environment

The White Paper on Environmental Management Policy is the overarching policy for the national management of the natural environment within South Africa. The policy sets out numerous principles, goals and objectives and delegates sections of government responsible for the various spheres of environmental management (RSA, 1997). This policy includes parameters for water resource management ensuring the long-term sustainability of this resource and associated natural environments and ecosystems such as river and wetlands through controls such as ecological reserve requirements (RSA, 1997). The ecological reserve is the minimum volume of water which must be retained within an aquatic environment to sustain natural ecological functioning (RSA, 1997).

Sustainable Growth and Development

Water is integral to the promotion of sustainable growth and development in South Africa. Continuous economic growth and the need for enhanced social development place substantial pressures upon the country’s water resources presenting numerous challenges for water management. South Africa is currently placing a major focus on economic growth within numerous sectors which include tourism, industry and agriculture (DWA, 2013a). The focus on increased growth within sectors which are heavily

water dependent will increase pressures on this limited resource, placing increased burden on national, provincial and local governments to come up with solutions to improve water resource management, conservation and development. These pressures are hard felt in urban areas given the high population concentrations, the inherent need for growth and development of the economy and the requisite of addressing pertinent social factors like human health and well-being. Sustainable growth and development within these urban areas is essential in promoting the NDP's vision 2030 of reducing inequality and poverty, creating jobs, transforming the urban space and promoting economic growth (DWA, 2013a).

Urban water resource management is pertinent in the promotion of the NDP and various development strategies within South Africa. The NDP and NWRS 2 provide guidance with regard to development within the country via the promotion of efficient and effective water resource management strategies (Armitage *et al*, 2014). Both the NDP and the NWRS 2 note that water is central to achieving social equality and economic development within South Africa however, according the DWA (2013a), despite this recognition by both documents water in the country still remains a secondary priority (Armitage *et al*, 2014). Water resources and the management of the urban water cycle, economic considerations, climate change adaption, resilience building and a heightened focus on capacity building are key focal points in achieving water sensitive cities and promoting development planning which exhibits sustainable economic growth and development and social equality.

Major Contemporary Issues and Status Quo

South Africa is a water scarce country receiving significantly less rainfall in comparison to the international average and is ranked internationally as the world's thirtieth driest country (DWA, 2013a). Water scarcity is exacerbated by high temperatures which drastically increase rates of evaporation, this coupled with high rates of freshwater pollution, are major contributors to water deficits throughout the country (DWA, 2013a). The high variability of the spatial distribution of areas with high levels of water runoff results in spatial inequality of water resource distribution across South Africa. High runoff rates in urban areas, given the lack of porous surfaces, results in numerous challenges for stormwater management including water drainage and pollution. Urban flooding is an ever present threat and along with droughts, are projected to increase in frequency and intensity as a result of climate change.

Water infrastructure is unevenly distributed throughout South Africa; a trend which is highly apparent within the country's urban areas. The costly nature of water infrastructure and a lack of monetary resources at an institutional level in together with a lack of capacity have resulted in the ageing of vital infrastructure throughout the country due to insufficient maintenance and upgrading. Inadequate and degraded infrastructure contributes significantly to the inefficient use of water particularly with regards

to wastage through faults or leakages within the systems (DWA, 2013a). South Africa has reached a point where water demand is exceeding supply placing significant pressures on demand side and supply side water management initiatives (DWA, 2013a). Groundwater presents a major opportunity in many parts of the country as a freshwater resource. The extraction and use of this resource could significantly increase supply, reducing pressures of demand (DWA, 2013a).

Urban development and industrial activity are the major contributors to poor urban water quality throughout South Africa impacting significantly on the freshwater resource and jeopardising environmental integrity (DWA, 2013a). Natural water systems in the majority of urban areas are regarded as of poor quality in environmental terms. This includes, but is not limited to, urban wetlands and riverine systems.

Conclusion

It is clear that water resources, when adequately aligned with national planning objectives, have the capacity to support sustainable growth and development and that the effective management of this resource can have positive impacts throughout the country. South Africa has robust water policy at a national level. National water policies are in alignment with national development goals and objectives and support the country's strategies to effect change and reverse the negative impacts of Apartheid. The responsibilities of national, provincial and local government bodies are well defined in national policy. In addition, national policy takes a holistic stance on water management, encompassing all water-related sectors and promoting coordination between these sectors. Despite strong national policy designed to guide water resource management at national, provincial and local levels, water management within urban areas is of significant concern. This is perhaps not surprising given the high demand of this resource for economic growth, social development and environmental integrity within these areas. National policy is essential for the effective management of South Africa's water resources and is clearly designed to guide water resource management throughout the country including management initiatives within urban areas. Chapter 5 aims to explore urban water management with a particular focus on Cape Town and aims to review current water management approaches in an endeavor to uncover the major issues related to the City's current approach to urban water management.

Chapter 5: Urban Water Management

Introduction

Effective and efficient urban water management promotes economic, social and environmental sustainability within urban environments. A high level of effectiveness and efficiency with regard to the management of this resource, is thus imperative to creating an urban environment which facilitates economic growth and development, addresses social issues, and ensures the protection and enhancement of the natural environment.

It is envisioned that urban settlements within South Africa should promote spatial equality, socio-economic enhancement, provide social and economic opportunities for all, promote sustainable growth, exhibit democratic governance and promote community driven initiatives. (RSA, 2016). Included in this vision is a strong focus on the protection and sustainable use of natural resources, public participation in all development initiatives, enhanced service delivery and improvements in the efficiency and effectiveness, and equitable spatial distribution, of infrastructure (RSA, 2016).

Water resource planning is fundamental to balancing water distribution between that required for economic growth and development and provision for domestic consumption and environmental functioning. The Social Assessment and Development Framework developed by the DWA guides water infrastructure planning in a manner which seeks to enhance the focus of attention on social needs (DWA, 2013a). Municipalities have however failed to adopt this approach in their planning initiatives and thus there is a need for innovative approaches to manage, conserve and develop urban water resources and the associated infrastructure to meet social, economic and environmental requirements (DWA, 2013a).

Increasing pressures from climate change and population growth on urban water resources are the major drivers behind the need for more innovative, ways in which to manage these resources (Carden & Armitage, 2013). Concerns with regard to water resources within urban areas include resource depletion, pollution, over extraction and exploitation, insufficient access to services such as wastewater removal, water supply and sanitation, and resultant negative impacts on human health and environmental integrity (Carden & Armitage, 2013). The following section aims review water resource management in Cape Town with the focus on water resources as central to promoting sustainable development in the city.

Cape Town

Sustainable Development in Cape Town

Cape Town faces numerous challenges similar to those found in cities around the world, particularly those of the global south. These challenges include rapid rates of urbanisation, urban population growth and increasing pressures for adaptation and resilience in response to changes in both global and local climatic conditions. There is a lack of international guidance with regards to policy designed to guide sustainable development in urban areas of the developing world (Swilling, 2010). In addition to those challenges faced by cities around the world, Cape Town is presented with a number of unique challenges which must be navigated in endeavors to promote sustainable development. Racial inequalities, as a result of Apartheid, persist and present a major contemporary challenge for local government which needs to promote equality in access to opportunities and resource distribution. Sustainable development requires economic growth and development in a manner which does not jeopardise environmental functioning and social development. International examples of ways in which to achieve this balance come predominantly from the global north with little precedence coming out of developing countries (Swilling, 2010). The cities of the global south must thus find innovative ways in which to overcome both global and local challenges in their endeavors to promote equality, sustainability and growth (Swilling, 2010).

Cape Town is characterised by major disparities in wealth distribution within its population of 3.5 million people. Approximately 50% of this figure are categorised as poor whilst the majority of the City's financial resources are controlled by 16% of the population (Swilling, 2010). Poor areas are characterised by major backlogs in the delivery of municipal services. High unemployment rates, rapid urban population growth, major inequality, service provision backlogs, pressures for economic growth and development, climate change and a lack of institutional capacity are all factors which the CoCT need to take into account when developing strategies for sustainable development (Swilling, 2010). Financial pressures on the City are mounting resulting in increased reliance on the National Government for financial aid (Swilling, 2010).

Cape Town is currently in a water crisis with some projections estimating that the city could run out of water by as early as March 2018 (Haden, 2017). Winter rains, usually received between the months of April and September, have been insufficient to raise dams water levels to adequately supply the city through the coming dry summer months. Furthermore, data indicates that this shortage is not an anomaly indicating a consistent annual decline in precipitation, and consequently declining peak dam levels, since 2014 (Haden, 2017). As discussed, water is a resource which is relied upon for the promotion of human health and well-being, economic growth and development, and environmental and ecological functioning. As a result, urban water resources, the management of these resources and

the infrastructure associated with this management, play fundamental roles in the promotion of sustainable development. Cape Town now faces the additional challenge of adjusting water management strategies to respond to limited water supply whilst simultaneously meeting multiple economic, social and environmental objectives. This section aims to focus on Cape Town's urban water cycle and the management thereof in an attempt to gain a further understanding of the inherent problems and to explore ways in which this management could be enhanced to respond to the current water crisis, in a manner which promotes sustainable development and creates a water sensitive city.

Urban Water Cycle

Cape Town is located within the Berg River Catchment in which it shares water resources with neighboring areas including Stellenbosch and Franschhoek. The city's water cycle is thus located within this catchment and water is a shared resource throughout the catchment. Cape Town's urban water cycle is much like other urban hydrological cycles around the world with attributers of evaporation, condensation, precipitation, water catchment and groundwater harnessing, water reticulation, and WWT (City of Cape Town (CoCT), 2017). Cape Town receives a rainfall average of approximately 500 mm/pa with the majority received during the winter months (April-September). As a result of the mountainous topography which typifies the city, the spread of rainfall is uneven throughout the area. The majority of the catchment areas on which the city relies for water supply are located to the east of the city whilst the catchments within the city contribute little to the total water supply (CoCT, 2017). A number of dams in this eastern area are responsible for capturing and storing rainwater and are relied upon by Cape Town for 98% of the water utilised within the city (CoCT, 2017). Groundwater within the city contributes approximately 2% to the total water supply. Aquifers upon which the city relies include the Atlantis Aquifer and the Albion Spring (CoCT, 2017).

The demand for water within Cape Town is increasing largely as a result of the same factors which contribute to increased demand both nationally and internationally; a changing climate, increased economic growth and development, and a growing population. The increased demand has resulted in the construction of additional dams in catchments to the east of the city and costly infrastructure, mainly pipelines, to deliver this water to be treated and to enter the urban reticulation system (CoCT, 2017). With continued economic growth and development, social development, population growth and environmental pressures, the city has been forced to consider alternative sources of water supply. The majority of these will require the installation of costly infrastructure such as the development of desalination plants to harness seawater and the diversion of river courses to supply additional dams (CoCT, 2017).

A series of interconnected infrastructural systems collect and channel stormwater runoff into natural waterways, which includes streams and rivers, throughout the city. Stormwater is then deposited into

the ocean either directly by infrastructural networks or by natural water ways (CoCT, 2017). A number of rivers have been canalised to cope with increased flow rates for the removal of stormwater from urban areas. The Black and Lotus Rivers are good examples of this. Non-porous surfaces such as tarred roads throughout the city have profound effects on stormwater runoff. Reduced infiltration rates diminish groundwater recharge and result in increased volumes of runoff. Surface pollutants are accumulated within this runoff reducing the potential uses for this water resource and presenting numerous environmental threats. These factors increase the risk of flooding, result in environmental degradation and impact upon human health and well-being (CoCT, 2009a).

Water treatment in Cape Town is characterised by a total of 12 treatment plants, despite the relatively high water quality supplied by the surrounding catchments there are a number of water quality issues including large volumes of sediment and high acidity levels (CoCT, 2017). These treatment plants are responsible for the removal of solid and particulate matter, lowering acidity levels, and the removal of harmful pathogens and bacteria which may reside within the water (CoCT, 2017). Treated water is delivered to reservoirs at various points throughout the city which are responsible for the storage of clean water. These reservoirs are a vital component of water reticulation as they are responsible for building pressure within the system (CoCT, 2017).

Cape Town's water reticulation system consists of three major networks namely; the potable water network, the non-potable water network and the wastewater network (CoCT, 2017). These networks are comprised of an infrastructure labyrinth which includes pipelines, pump stations and reservoirs. Non-potable water is the smallest of these networks and is responsible for the reticulation of treated wastewater to various points where it is utilised for a number of functions which include industrial use and irrigation (CoCT, 2017). The management of these systems requires an extensive operation which is responsible for infrastructure installation, upgrading and maintenance. The treatment of wastewater involves 17 treatment plants which treat both greywater and blackwater (CoCT, 2017). Treated effluent from wastewater treatment works (WWTWs) is deposited into various water systems including groundwater reserves, riverine systems, pipelines or canals which deliver the water to the ocean (CoCT, 2017). Water is treated to a quality which is deemed safe for environmental consumption but is not acceptable for potable use. A number of WWTWs within Cape Town are currently operating over capacity jeopardising the quality of the effluent entering natural systems throughout the city (WRC, 2011). In some instances the water is provided for industrial or irrigation purposes.

The CoCT provides approximately 3.74 million people with potable water and sanitation services (CoCT, 2017). Water within the city is provided for predominantly domestic, commercial and industrial uses

for which consumers are required to pay a monthly fee (CoCT, 2017). Approximately 5% of all water consumed in Cape Town is recycled (CoCT, 2017).

Urban Water Management

The responsibility of the different spheres of water management within the CoCT is divided amongst three separate departments, the Water and Sanitation Department, the Roads and Stormwater Department and the Environmental Management Department.

The CoCT Water and Sanitation Department has adopted the Water Conservation and Water Demand Management Strategy (WCWDMS). This strategy has been adopted by the City as a means to respond to growing demands for water resources, particularly those relating to wastewater and bulk water infrastructure (CoCT, 2013). In 2001 a study conducted by Integrated Water Resource Planning (IWRP) indicated that the WCWDMS was the most appropriate means to manage the growing demand for water within the city (CoCT, 2013). The aim of this strategy is, “to ensure the long-term balance between available water resources and water demand, to postpone the need for expensive capital infrastructure projects for as long as it is economically viable and to minimise water wastage”(CoCT, 2013:1).

The strategy focusses on three major points: 1) combining the needs of present water demand whilst accounting for future increases in demand, 2) the protection of the natural environment by limiting the negative impacts of abstraction from natural water bodies and, 3) ensuring that water services is a financially viable business (CoCT, 2013). The major benefits of this strategy include reducing uncertainty of future water demand, postponing large infrastructural investment, promoting job creation, and ensuring sustainable water supply to communities (CoCT, 2013).

The CoCT Roads and Stormwater Department is responsible for the management of stormwater and stormwater infrastructure within Cape Town. Two policy documents guide stormwater management within the city; the Floodplain and River Corridor Management Policy (FRCMP) and the Management of Urban Stormwater Impacts Policy (CoCT, 2009b). These policies seek to mitigate development within areas prone to flooding to enhance the protection and integrity of the natural environment, and protect developed areas by rapidly removing stormwater runoff, respectively (CoCT, 2009b).

Local municipalities are responsible for the management of stormwater within urban areas as mandated by the Constitution (Armitage *et al*, 2014). The CoCT Roads and Stormwater Department promote the principles of WSUD within the Management of Urban Stormwater Impacts Policy largely as a result of international pressures of best practice (CoCT, 2009a). The policy aims to create resilience amongst local communities by reducing the risk of flooding and protect the city against negative

economic, social and environmental outcomes as a result of flooding such as human-health concerns, damage to businesses, damage to infrastructure and environmental degradation (CoCT, 2009a).

The stormwater management approach within Cape Town is to develop guidelines designed to inform development initiatives. These guidelines include the Stormwater Management Planning and Design Guidelines for new developments and the Floodplain Management Guidelines (CoCT, 2009a). Despite these policies and guidelines the City appears to lack a comprehensive approach to the management of urban stormwater.

The CoCT Environmental Management Department is responsible for managing the city's fresh water resources. The management of these resources requires continuous monitoring of fresh water systems to locate the source of pollutants and ensure that other municipal sectors are upholding the standards of water quality, for example WWTW's (CoCT, 2003a). This department promotes a high standard of water quality throughout the city in order to uphold environmental integrity, protect biodiversity and ecological systems, and ensure that water does not pose a threat to human health (CoCT, 2003a).

Cape Town's Integrated Metropolitan Environmental Policy (IMEP) promotes improved environmental water quality, legislative compliance of WWT facilities and the efficient management of environmental water resources (CoCT, 2008). These are the major environmental focus points for the management of environmental water resources as per the IMEP's vision for the year 2020. This policy promotes an environmental management approach which recognises water as a scarce resource, recognises groundwater as a valuable resource, promotes the need for sustainability through water demand management, upholds and improves environmental water quality and ensures compliance of WWT facilities (CoCT, 2008). The policy commits itself to, "ensuring that the quality of coastal, marine and inland waters of the City of Cape Town is suitable for the maintenance of biodiversity, the protection of human health and a commitment to the principle that all CCT inhabitants have the right to clean, potable and adequate water sources"(CoCT, 2008:9).

Urban Water Management Concerns

There are a number of major concerns with regard to water management within Cape Town and the Western Cape. Inadequate institutional capacity and financial resources within municipal departments responsible for the management of water resources and the delivery of water related services. As a result, a lack of continuity and coordination within water resource management and planning (Western Cape Government (WCG), 2012). As of 2007 a total of 40 000 households remained without sanitation services and 30 000 lacked water delivery services (Swilling, 2010). These figures indicate severe service delivery backlogs within the city. Inadequate cost recovery for the provision of municipal water services

by local municipal departments has diminished municipal funds and perpetuated service delivery backlogs (Swilling, 2010).

Water related infrastructure is aging, resulting in major water losses. A lack of capacity, largely due to an increase in demand, of numerous water-related infrastructure, including water reticulation systems and WWTWs has resulted in reductions in efficiency which has varying, city-wide, consequences (WCG, 2012). Inadequate maintenance and upgrading of existing infrastructure has placed significant pressure on these systems and resulted in a major reduction in their effectiveness and efficiency (WCG, 2012). Investment by the City into the upgrading and maintenance of existing infrastructure as opposed to promoting infrastructure development has perpetuated service delivery backlogs and capacity issues.

Despite the fact that WCWDMS has potential within Cape Town, the implementation and management of this strategy has been a slow process and monitoring initiatives are not currently regarded as adequate (WCG, 2012). In addition, this strategy has produced limited results in terms of increasing the efficiency of water use and promoting water savings (WCG, 2012).

Concerns pertaining to ecological sustainability are largely as a result of over abstraction from natural water bodies, inadequate monitoring and over allocation which has resulted in deficits in the requirements of the ecological reserve. Planning initiatives must consider Critical Biodiversity Areas (CBAs) and National Freshwater Ecosystem Priority Areas (NFEPA's) in the promotion of environmental, social and economic factors as highlighted by the Provincial Spatial Development Framework (PSDF). Climate change, population growth, economic development and other factors which are expected to either reduce water supply or increase demand are of major concern as they place considerable stress on water resources (WCG, 2012). This has implications for economic growth and development and concerns over perpetuating inequality resulting in greater societal divisions (Carden & Armitage, 2013).

The factors responsible for the deterioration of water quality must be addressed. These factors include solid and dissolvable pollutants accrued from numerous sources such as stormwater runoff, agricultural activities in water catchment areas and, among numerous others, effluent from non-compliant WWTW's (WCG, 2012). The reduction in water quality has significant impacts on the cost of water treatment, human health and well-being, and the integrity of the natural environment. This deterioration includes the water quality within aquifers and other groundwater sources which require intensive monitoring and management (WCG, 2012). Despite stormwater management policy promoting SuDS this policy has not been adequately transferred into stormwater infrastructure and management. Management approaches continue to regard stormwater as a nuisance and seek its rapid removal from urban areas (Armitage *et al*, 2014).

Planning is an important component of water resource management and must promote sustainable development by recognising the finite nature of water resources, reducing risk and building resilience among local communities (WCG, 2012). Failing to coordinate and integrate water resource management within spatial planning initiatives could have disastrous consequences. ‘Silo management’ of the various water related sectors has created disconnection between the management of water resources within the city. The lack of coordination between these sectors and planning initiatives, largely in terms of policy and management approaches, is resulting in missed opportunities with regard to the enhanced and sustainable management of water resources. There appears to be a lack of devolution from national to regional to local water related policy and concerns surrounding conflicting policies and the inconsistencies between these policies and management approaches have come to the fore (WCG, 2012).

Compliance with National Policy

Overall the CoCT urban water management approach exhibits little compliance with national policy. The City did not respond adequately to NWRS concerns of declining water resources indicated by data as early as 2003 (DWA, 2013a). This includes an inadequate response to more recent data which indicates consistent reductions in annual rainfall and peak dam levels since 2014 (Haden, 2017). There is limited adherence to national policy in the promotion of coordinated catchment-wide water resource management with little coordination exhibited by Cape Town’s urban water management and the overall management of water resources within the Berg River Catchment. Water management within the city is in breach of the NWA in the CoCT’s failure to provide all citizens with adequate access to safe drinking water and sanitation services.

Urban stormwater management practices fail to adhere to national policy requirements in preventing harm to the natural environment and human health and well-being. Current stormwater management practices do not regard stormwater as a valuable resource and seek to dispose of, often polluted, stormwater into the closest water course (Armitage *et al*, 2014). This has negative ramifications on the health of local community members and the natural environment and is regarded as largely unsustainable (Armitage *et al*, 2014). Local municipalities often exhibit non-compliance with considering stormwater within the required WSDPs drastically inhibiting holistic water resource management (Armitage *et al*, 2014). The failure of urban stormwater management to adhere to national policy is largely attributed to limited financial resources within the local municipality (Fisher-Jeffes & Armitage, 2013).

National policy demands more stringent controls on groundwater abstraction however Cape Town has little to no regulatory frameworks in place. This has resulted in inequitable abstraction of groundwater

resources skewed largely toward middle to high income groups who have the means to afford private infrastructure associated with groundwater abstraction. Limited regulation could have a variance of social and environmental impacts as users are not held accountable to any regulations associated with abstraction rates and subsequent water uses. Over abstraction depletes groundwater resources and can have profound effects on surface conditions. In addition concerns of poor water quality can impact the natural environment and human health and well-being.

The Need for an Alternative Approach to Urban Water Resource Management

Despite strong national policies it is clear that urban water management in Cape Town exhibits limited compliance to these policies. Limited compliance to national policy coupled with additional issues inhibiting adequate urban water management in Cape Town has drastically reduced the city's scope to promote sustainable development and meet a range of economic, social and environmental objectives. The issues which currently inhibit adequate water management and service delivery within Cape Town pertain largely to, and are exacerbated by, a lack of municipal resources and capacity to effectively and efficiently translate national water and development policies into effective local management strategies. Water resource infrastructure is ageing and a lack of upgrading and maintenance and the high costs associated with installing new infrastructure have placed significant pressure on municipal departments and local water resources.

Concerns pertaining to urban water management in Cape Town are both exacerbated by, and themselves exacerbate, the drastically reduced water security throughout the Western Cape Province. The current drought has resulted in the long overdue need to rethink water management approaches within the city and requires innovative solutions in overcoming chronic water shortages (Naidoo, 2017). Alternative approaches will be required in order to facilitate a response in the need to enhance water security within the city through appropriate water resource management which will require adaptation across all sectors (Naidoo, 2017). In addition, alternative approaches must respond to the need for sustainable development and various national, provincial and local economic, social and environmental objectives whilst taking into consideration, and addressing, limited financial resources and capacity within local water-related municipal departments. The section to follow aims to consider WSUD and its ability to contribute to enhancing urban water resource management in Cape Town.

Chapter 6: WSUD as an Alternative Water Management Approach

Introduction

It is clear that Cape Town requires an alternative approach to manage its urban water resources. It is proposed herein that the City adopts a WSUD approach to urban water management so as to build resilience within local communities, promote sustainable development and, in so doing, create a water sensitive city. WSUD has the ability to increase available water resources, promote equality among all citizens of the city and increase resilience against the adverse effects of climate change (Armitage *et al.* 2014). WSUD promotes an objective contained within the National Climate Change Response White Paper that, “urban infrastructure planning must account for water supply constraints and impacts of extreme weather related events”(RSA, 2011b:22).

WSUD as a Water Management Approach for Cape Town

Cape Town is characterised by a unique landscape which includes coastal zones, mountains, large flat areas with gentle topography and numerous rivers and streams. WSUD enables a management approach which can adapt to this specific topographical environment whilst also taking into account the impacts of the physical, built-form of the city on the urban water cycle.

WSUD provides Cape Town with an opportunity to manage water resources in a holistic, transdisciplinary manner. WSUD is pro-development thus the adoption of this management approach will not hinder economic growth and development, but rather, promote it. Not only does WSUD promote development it promotes developments which are economically, socially and environmentally sustainable contributing to the overall long-term sustainability of Cape Town.

The adaptive and flexible nature of WSUD allows it to be implemented at numerous spatial scales promoting greater opportunities for urban water management within Cape Town. Given the need for a range of innovative solutions to the current water crises, WSUD can fill a number of niche areas which demand attention. For example, WSUD can be implemented at the household level or could be incorporated within city wide interventions. Moreover, WSUD can be utilised alongside, or retrofitted to, existing water infrastructure and presents opportunities for reducing pressures on these systems and enhancing the management of water resources.

Public and stakeholder participation are currently being encouraged within Cape Town, particularly pertaining to new developments. WSUD promotes stakeholder participation, recognising it as a means to maximise results and benefits to local people. The City recognises stakeholder engagement as an essential part of the planning process

Stormwater is currently directed to the coast via a series of drainage networks, including natural systems, and discharged into the sea, this is made easy given Cape Town's close proximity to the Atlantic Ocean. The inability to capture this freshwater at a point downstream from the urban area has resulted in the greater need for inner-city stormwater capture and storage solutions such as those that WSUD provides. WSUD's recognition of stormwater as a valuable resource affords Cape Town the opportunity to re-evaluate the management of this resource in a manner which promotes its retention and use within the city. The use of SuDS, inherent to the WSUD approach, provides a means through which to promote this management approach and reduce municipal expenditure on infrastructure.

Groundwater is currently an underutilised source of water in Cape Town, and as mentioned previously, accounts for approximately 2% of the city's total water supply. The infiltration of highly polluted runoff poses a major threat to the quality of the city's groundwater. WSUD provides a means through which to manage surface runoff and place controls designed to reduce pollutants from infiltrating this resource. The holistic management of water resources in Cape Town will promote more stringent controls on the use and abstraction of groundwater and the activities which pose a potential threat to this resource.

The principles and infrastructure promoted by WSUD protect and enhance green open space, providing high quality urban spaces. In addition, the approach seeks to enhance the protection and conservation of a variety of natural environments including ecologically sensitive areas throughout the city promoting increased provision of ESSs. Environmental protection and the provision and enhancement of green open space form part of Cape Town's Spatial Development Plan (SDP).

Many communities in Cape Town, especially the urban poor, are highly susceptible to, and often the most harshly affected by, extreme weather events such as flooding and drought. In addition, spatial inequality within Cape Town, as a result of Apartheid town planning schemes have resulted in a lack of adequate service provision to many of the urban poor. Many of these communities lack adequate stormwater drainage infrastructure, sanitation services and water supply. The application of the principles of WSUD within Cape Town can be utilised to combat these issues. Resilience building and improved sanitation and water supply are factors which drastically improve human health and well-being.

WSUD can also be highly beneficial to Cape Town if integrated into water management strategies in higher income areas, promoting environmental sustainability and reducing pressures on existing infrastructure. The notion of 'developer pays' reduces dependencies on the local municipality in supplying water-related infrastructure and services thus affording municipal departments the opportunity to redirect large amounts of financial resources and investment interests away from areas

where developers' interests are greatest, toward low-income areas where there is currently inadequate service provision. Furthermore, Cape Town can utilise these financial resources to upgrade and maintain existing water related infrastructure throughout the city. WSUD can also be utilised as a means to promote inclusivity within developments which target high income residents.

WSUD has the capacity to address and promote multiple national and local objectives such as water demand management, stormwater management, groundwater management, environmental concerns, sanitation services and water supply at a variance of scales. As previously noted, water plays a vital role in economic growth and development, by addressing multiple objectives through a variety of principles and infrastructure. WSUD can enhance economic growth and development through an increase in water supply whilst simultaneously addressing a number of social and environmental concerns throughout the city. As a result WSUD is a management approach which facilitates sustainable development, promotes national policy and can aid Cape Town in a movement toward a water sensitive city.

Challenges to Implementing WSUD in Cape Town

The compartmentalisation of the various water management functions across different municipal departments drastically reduces coordination between these departments, government institutions and spatial planning initiatives. Municipalities must be responsible for the coordination of water management in order to combine cross-sectoral demands and issues (Armitage *et al*, 2014). The current lack of coordination between municipal departments is perhaps most apparent in the management of stormwater by the Roads and Stormwater Department. The holistic nature of the WSUD approach requires the CoCT to manage water supply, sanitation services, stormwater management, WWT, groundwater management and environmental management under a single, holistic, management framework. This will require the costly and time consuming process of institutional and municipal restructuring.

A major constraint to adopting WSUD in Cape Town is, "a lack of enabling council approved policy and guidelines"(Armitage *et al*, 2014:41). Relevant water policy within Cape Town will require amendment to promote the principles of WSUD within the City's water management strategies. It is clear that the concept of WSUD is beginning to surface within policy in Cape Town. WSUD has been incorporated within stormwater policy as a means to achieve the objectives of the CoCT's Integrated Development Plan (IDP) namely to, "Reduce the impacts of flooding on community livelihoods and regional economies [and] safeguard human health, protect natural aquatic environments, and improve and maintain recreational water quality"(CoCT, 2009a:5). The CoCT indicates its commitment to the instillation of WSUD infrastructure such as SuDS stating outright that, "Water Sensitive Urban Design

principles will be incorporated into urban development through the application of sustainable urban drainage systems”(CoCT, 2009a:8).

Despite the promotion of WSUD within the City of Cape Town’s stormwater management policies little has changed in aligning infrastructural development and water resource management within this policy and, as a result, the implementation of SuDS within management approaches has, to date, been unsuccessful. Given the primary objective of the Roads and Stormwater Department to construct and protect public infrastructure, stormwater remains treated as a possible threat and is dealt with by a series of drainage networks responsible for its rapid removal from urban areas. Furthermore, promoting WSUD in a single sector of water resource management is ineffective as the approach requires comprehensive coordination between sectors to holistically manage the urban water cycle and achieve successful outcomes.

In essence, the challenges associated with the implementation of WSUD pertain largely to time and cost. Cape Town requires immediate adjustments to water management approaches given the current circumstances of drastically reduced water security as a result of a prolonged period of drought. Amendment to legislation, institutional rearrangement, policy reform and the transferal of policy into management strategies are extremely time consuming and costly processes. Limited resources and a lack of institutional capacity present the greatest challenges to transforming water management approaches within Cape Town. Resource deficits are perpetuated by the inability of local municipalities to recover costs from numerous infrastructural investments (Armitage *et al*, 2014). Cape Town’s municipal water departments face severe service delivery deficits, over capacitated infrastructure, and infrastructural failure and supply shortages. These departments are thus pressurised to direct their limited financial resources toward addressing these issues and seeking alternative water supplies, i.e. desalination plants. It is clear that the current drought and associated water crisis faced by Cape Town is intensified by a lack of municipal resources and current urban water management shortcomings. It would be unreasonable, under these circumstances, to rely solely upon municipal water departments in Cape Town to transform urban water management within the city. It is clear that the adoption of WSUD would deliver numerous benefits to Cape Town however the City will require an innovative approach through which to implement this strategy in a manner which takes into account the limitations discussed herein.

Conclusion

The challenges associated with the implementation of WSUD and reforming urban water management in Cape Town indicate that a complete transformation of this management approach will be an extremely costly and time consuming process. Despite the cost associated with the implementation of

WSUD it is vital, given the current water crisis, that Cape Town consider immediate alternative water management solutions. Innovative solutions to overcome the challenges discussed above must be sought by the City in implementing WSUD. Chapter 6 discusses ways in which WSUD can be promoted in Cape Town and the role of spatial planning in catalysing a systemic transition in urban water management.

Chapter 7: Implementing WSUD in Cape Town

Introduction

The implementation of WSUD at a city scale requires numerous policy amendments, institutional rearrangement, and infrastructural development. Implementing WSUD and creating water sensitive cities is thus heavily dependent on the availability of resources within local government. This presents a major challenge in South Africa, and by extension in Cape Town, given the lack of financial resources and institutional capacity required to bring about a transformation in urban water management (Armitage *et al*, 2014).

It is clear that Cape Town requires the adoption of alternative water management options and international precedence has indicated WSUD as a viable management approach. It has been noted that the implementation of WSUD would differ significantly between cities of the global south and those of the global north as cities, even between those of developing countries, each face unique circumstances and challenges. The major challenges faced by Cape Town include a lack of coordination between municipal departments responsible for water management and service delivery, the need to upgrade and maintain ageing infrastructure, the need for alternative sources of water supply, costly and time consuming nature of institutional rearrangement, policy amendment and translating policy into action and numerous spatial challenges, all of which are exacerbated by limited resources.

Systemic Transitions through Spatial Planning

Spatial planning within processes of urban transitions is recognised predominantly as a means through which to ensure implementation of desired actions. Its capabilities as a means through which to promote and catalyse an urban transition are largely overlooked. Spatial planning has considerable influence over the distribution of resources thus influencing the spatial distribution of economic investment into systems such as infrastructure, transport and water. Spatial planners base decisions on a wide variety of policy and social, economic and environmental conditions so as to ensure that the outcomes of spatial interventions are beneficial to all both in the short and long-term. In addition, it exhibits capacity to overcome barriers such as scale, multi-actor participation and uncertainty providing adaptive and flexible solutions.

Spatial planning, utilising the principles of WSUD, can facilitate the implementation of alternative water management approaches and infrastructure which operate at a variance of spatial scales. Spatial planning and WSUD exhibit similar principles and characteristics in that they both require a holistic, interdisciplinary, approach. Processes of public participation and stakeholder engagement and, in some instances, partnerships between the public sector and the private sector to support spatial interventions are essential to ensure successful implementation and outcomes. Limited resources and

a lack of coordination between municipal departments are the main barriers which Cape Town faces in successfully bringing about systemic change in urban water management. It is thus proposed that spatial planning, through its interdisciplinary nature transcending sectoral and professional boundaries, ability to operate at numerous scales, capacity to address numerous spatial objectives, ability to incorporate public participatory processes and its ability to operate between the public and private sectors, has the capacity to bring about a systemic transition in Cape Town's approach to urban water management.

The three major objectives presented by WSUD; to protect hydrological processes, increase community resilience and improve urban water resources can be incorporated within spatial objectives. Incorporating these objectives within a variety of systems inherent in spatial plans provides a measure through which to enhance their success. The principles and infrastructure associated with WSUD can then be applied spatially guided by these spatial plans promoting sustainable development through well-structured plans to enhance numerous economic, environmental and social factors.

An interdisciplinary approach requires the boundaries between disciplines to be transcended in a manner which enables these disciplines to work together, influencing one another in a collaborative manner (Tress, 2003). Interdisciplinary approaches promote increased coordination between the various stakeholders which, especially within the complex nature of the urban landscape, result in the reduction of uncertainties promoting more efficient and effective outcomes. The interdisciplinary processes inherent to the development of spatial plans provide a platform for the inclusion of WSUD within a variety of the spatial systems within these plans. Arguably the most advantageous for Cape Town is the ability of spatial planning to increase coordination between various municipal departments including the Roads and Stormwater, Water and Sanitation and Environmental Departments. The ability of spatial planning to increase coordination and collaboration between these departments would reduce the need for costly and time consuming institutional restructuring. Although the restructuring of municipal departments will be required in the future the immediate need for an alternative water management approach and the current lack of institutional capacity present major challenges with regard to this endeavor. Increased coordination will promote the holistic approach to water management that WSUD advocates and, as a result, will reduce redundancies within municipal infrastructural development and will increase both the efficiency and effectiveness of water management throughout the city. In addition, an interdisciplinary approach will enable WSUD to be deeply engrained within spatial plans when incorporated within other disciplines and fields. For example, including environmental, transport and health consultants and municipal departments in the conception of spatial plans provides deeper insights into spatial issues and system dynamics enabling

informed planning and as a result informing appropriate WSUD interventions. This increases the overall validity of these plans.

Spatial planning has the capacity to, and should, facilitate the participation of members of the public in the development of spatial plans further increasing the validity of these plans through community acceptance and buy-in. Public participation within this process is vital as it provides an opportunity for knowledge generation by opening channels for local community members and other stakeholders to voice their ideas, concerns and needs (Innes & Booher, 2000). The incorporation of local knowledge within the development of spatial plans provides valuable insights to local conditions that may have been, up until that point, overlooked. For example, local community members will be able to identify areas most susceptible to flooding or areas which lack sufficient water supply. These informants are imperative in WSUD decision making to ensure that the most appropriate infrastructure and management approaches are used and that their spatial distribution promotes effective outcomes. Incorporating public participatory processes within spatial planning also promotes social justice by providing all within a community a voice (Innes & Booher, 2000). All these advantages of public participation culminate to provide one major advantage and that is the enhanced legitimacy of the resultant spatial plans provided that the participatory process reflected fairness and democracy.

The ability of spatial planning to have an influence at a variety of spatial scales enables the implementation of WSUD from a local level to a regional level. The ability to influence and support implementation at the local scale is vital to the promotion of a systemic transition via a bottom-up approach. Furthermore, spatial planning enables greater collaboration between private and public initiatives, which is in line with the interdisciplinary nature of spatial planning discussed above. It is argued here that the implementation of WSUD in both the private and public realm can serve as a means to reduce pressures on municipal resources.

Poor communities in Cape Town must contend with private property developers who demand the attention of local municipal departments. These developers present large financial investment interests for the city thus resources are commonly directed to these developments to facilitate economic growth and development. It is argued here, that under the guidance of spatial planning, the implementation of WSUD can be funded, at least in part, by the developer within the development. Private developers would thus bear some of the cost in implementing WSUD interventions within their developments reducing pressures on municipal services and the need for additional municipal infrastructure. There are numerous incentives for developers to incorporate the principles of WSUD within development plans. These include enhanced open space, reduced reliance on local municipality for services, on-site flood risk management reducing infrastructure damage and, among others, long-term sustainability.

Where applicable developers and the local municipality can collaborate in planning processes where off-site interests benefit both the developer and local communities. These partnerships could, for example, serve to upgrade local ecological and environmental systems such as wetlands and rivers in a manner which reflects the principles of WSUD once again facilitated by spatial planning.

WSUD provides an opportunity for local municipalities to redirect financial resources away from upmarket developments and focus on the upgrading and provision of water related infrastructure and services to the urban poor. Spatial planning, through its interdisciplinary approach, public participatory processes and ability to influence development across an urban area has the capacity to identify areas where investment is required and bring about this change through spatial strategies which incorporate the needs of these areas. The ability of spatial planning to focus on local scale interventions thus provides a mechanism through which a bottom-up approach to systemic transitions can be achieved. This change will ultimately provide conditions under which legislation, policy and institutional arrangements can reform and undergo a transformation to reflect an overall transition in urban water management. In this manner, the incorporation of WSUD within spatial planning provides a strategy through which to promote a systemic transition in Cape Town's water management and contribute to creating a water sensitive city promoting long-term sustainability.

[A Model for Implementing WSUD in Cape Town](#)

The diagram presented in Figure 5 situates spatial planning and urban design as a function of WSUD. This model does not regard spatial planning and urban design as mechanisms capable of bringing about a systemic transition but rather as processes within the greater WSUD framework. This model presented in figure 5 requires reconfiguration if it is to adhere to the paradigm discussed above which highlights the capacity of spatial planning and the associated discipline of urban design to bring about systemic change.



Figure 7: Proposed Model for Implementing WSUD in Cape Town

Figure 7 is a representation of the proposed role of spatial planning and urban design in implementing WSUD and promoting a systemic transition. The flow diagram indicates the inclusion of the private and public sectors, numerous professions and disciplines, members of the public and other stakeholders in the development of a spatial plan guided by incorporating WSUD with other spatial informants and objectives identified within the interdisciplinary process. The infrastructure and principles of WSUD are then implemented within the implementation process of the spatial plan. Implementing WSUD in a simultaneous manner with other spatial objectives places WSUD within other urban systems and is thus viewed as vital to creating an overall holistic and sustainable urban system.

Conclusion

Spatial planning and associated processes of urban design possess the capacity to catalyse an urban systemic transition through a bottom-up approach by incorporating WSUD within additional spatial objectives in the development of a spatial plan. Promoting Interdisciplinarity, public participation and targeting multiple objectives within spatial planning enhances the effectiveness and efficiency of these plans to promote sustainable development. Spatial planning, it is argued, has the capacity not only to implement WSUD interventions but to guide Cape Town toward an alternative urban water management approach and, in so doing, bring about a systemic transition. The case study on the proposed development of the River Club aims to indicate how spatial planning can implement WSUD principles and objectives by incorporating these with other spatial informants, objectives and strategies. It also aims to highlight how WSUD and spatial planning inform one another in the development process of a spatial plan.

Chapter 8: Case Study: River Club

Introduction

The River Club is a site in Cape Town which has received considerable attention in recent years as a result of numerous propels to promote the development of this land. The site is falls within Two Rivers Urban Park (TRUP) and contains significance heritage, environmental and cultural value. Its location within Cape Town and current land-use has generated much debate around appropriate development options in aligning with the spatial objectives of the CoCT. This debate includes numerous social, economic and environmental factors. The focus on the River Club as a case study is largely due to high levels of public interest and public participatory processes already incorporated within current processes of spatial plan development. The availability of private resources, inadequate district level water service infrastructure, the spatial significance of the site and the inherent need for sustainable development within the area are additional factors identified as relevant in the selection of the River Club for this case study. Taking these factors into consideration it is maintained herein that the application of the principles of WSUD within the plans for the development of the River Club will serve as a catalyst for this approach to be incorporated in spatial plans throughout Cape Town.

It must be noted that the considerations of water management, although intrinsically linked to multiple others, is one component of the spatial planning and urban design process. This case study serves to demonstrate the ability of spatial planning to incorporate WSUD principles and infrastructural solutions in enhancing urban water metabolism and the spatial informants these, in turn, provide. In addition, the ability of the principles and infrastructure of WSUD to promote multiple spatial planning and urban design ideals is also demonstrated.

This case study is limited in its capacity to fully demonstrate the process of developing a spatial plan as it does not incorporate interdisciplinarity nor public participatory processes. As such the findings herein are merely conceptual and should be used as informants in plans rather than be regarded as final spatial plans and interventions.

Contextual Analysis

The River Club is situated within Two Rivers Urban Park (TRUP), Cape Town, South Africa, occupying a total area of 5561 m² (Planning Partners, 2016). TRUP is regarded as, “a special and unique place in Cape Town comprising sensitive ecological systems and habitats, extensive open space areas, significant institutions, historical buildings and cultural landscapes”(CoCT, 2003b:1). TRUP has been targeted by the Western Cape Provincial Government as a strategic area in which to target development, increase investment, unlock the spatial disconnections that exist within Cape Town and promote a more inclusive city (City Think Space, 2012). The River Club’s location within TRUP in terms

of its proximity to ecologically and environmentally sensitive areas, its open space, lack of accessibility and the spatial disconnect it creates between the western and eastern parts of Cape Town make the site an integral component in achieving the vision set for TRUP and future spatial development within the city of Cape Town (City Think Space, 2012).



Figure 8: Locating the River Club within TRUP (ESRI, 2011)

Natural Systems

The River Club lies in the lower reaches of the Slat River Catchment and is bordered by the Liesbeek River to the west and the Black River to the east (Whittemore *et al*, 2004). The Salt River Catchment has been significantly altered from its natural state by urbanisation. Impermeable surfaces, modification of natural drainage systems and the urban heat island effect are all contributors in altering the hydrological functioning within the catchment (Whittemore *et al*, 2004).

The Liesbeek River has strong ecological, heritage, historical and cultural significance to the city of Cape Town, however it has been subject to degradation over many years as the city has continued to develop (Wheeler, 2015). Canalisation, development within the floodplain, stream channel modification and removal of indigenous vegetation are among a number of contributors to the degradation of this system (Wheeler, 2015). A man-made canal, designed to divert the flow of the Liesbeek River as a flood prevention strategy, forms the south eastern border of the site reducing flow in the original stream channel to the west. High levels of degradation, particularly in the original stream channel, have resulted in efforts from various groups, which include Friends of the Liesbeek River and Working for Water, to restore and protect this water course with community mobilisation efforts to remove alien invasive species, reintroduce indigenous vegetation and various measures to improve the quality of its waters (Wheeler, 2015).

The Black River is characterised by low water quality and high levels of degradation (Day & Clarke, 2012). The lower reaches of this river are host to significant low lying wetlands including the Raapenberg Wetland which is listed by the City of Cape Town's Biodiversity Network as a Critical Biodiversity Area (CBA) (WPI, 2011; Belcher & Grobler, 2016). The Liesbeek and the Black Rivers are both listed as protected areas (SRK, 2017).

The River Club, as a result of its location within the Liesbeek and Black River Floodplain, is highly susceptible to flooding as it falls within the 1:100 year floodline. A high groundwater table throughout the site, between 2 and 4.5 meters below ground level, increases flood risk (SRK, 2017). The presence of the Atlantis Aquifer and the Malmesbury Group Aquifer are major contributors to groundwater resources (SRK, 2017).

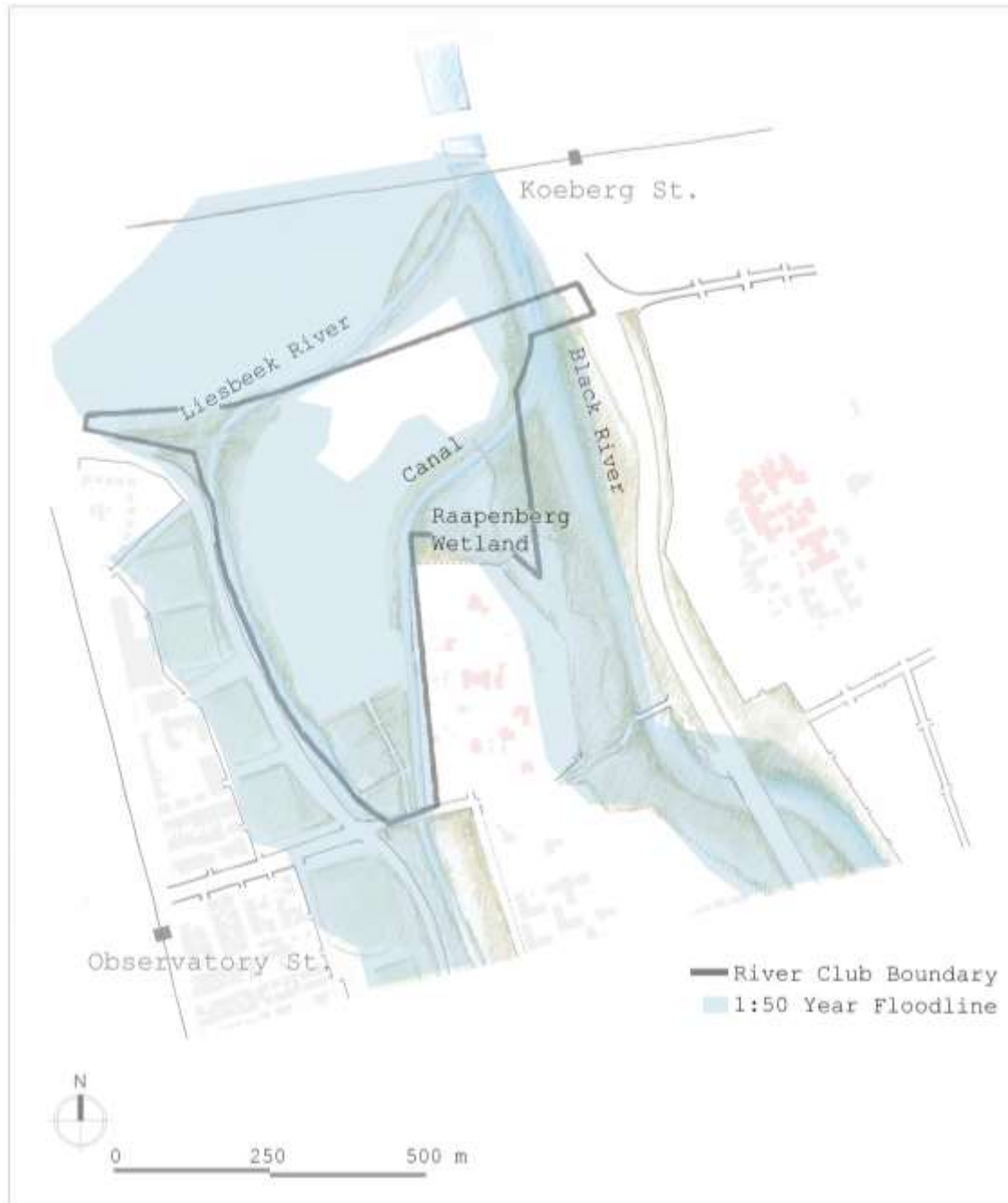


Figure 9: Delineation of the 1:50 Year Flood line in Relation to the River Club (Adapted from Gluckman & Lubbe, 2016)

Development

The River Club, currently zoned as ‘private open space’, has low levels of infrastructural development, land-use on the site is currently limited to a driving range, a small 9-hole golf course, a function venue and a restaurant (SRK, 2017). There are current plans proposed for the development of the River Club to accommodate a mix of land-uses which include residential, commercial and, among others, institutional uses. These plans propose a total development area of 7.4 hectares (ha) of the total erf size of approximately 15.7 ha (SRK, 2017). The plans indicate that the remaining 8.3 ha are to be a

combination of open space (4.6 ha), landscaped portions and pedestrian and other non-motorised transport (NMT) routes. The proposal for the development on the site includes a number of alterations to the natural landscape which include earth works to raise the elevation of the site above the 1:100 year floodline and the recommissioning of the original Liesbeek River Channel to the west of the site (SRK, 2017).

Social and Environmental Concerns

The development could result in negative impacts on a number of social and environmental factors. As the River Club is situated in close proximity to sensitive ecological systems mitigative measures must be taken to ensure that these systems are not harmed by any on-site activities and where possible take measures to further promote the conservation and well-being of these systems (SRK, 2017). There are numerous concerns pertaining to surrounding water resources which include watercourses and groundwater. Development activities can result in the further modification of these systems which include altering hydrological functioning and the contamination and further pollution of these resources (SRK, 2017). The proposed development must be sensitive to the cultural and historical value of the site and the integrity of these sites, including those linked to heritage, must be upheld by any and all infrastructural development including all water related infrastructure. The physical structure of Cape Town is one which exhibits exclusionary characteristics largely as a result of Apartheid. It is imperative that all new developments address this historic structure in a manner which seeks to create a more connected, equitable and inclusive city, one in which all have equal access to opportunities. The nature of the site given its close proximity to the city centre, its past role as a spatial buffer between areas and its surrounding rich natural resources and heritage is one which requires serious consideration toward social factors and ways in which it could impact positively on the city of Cape Town and its people.

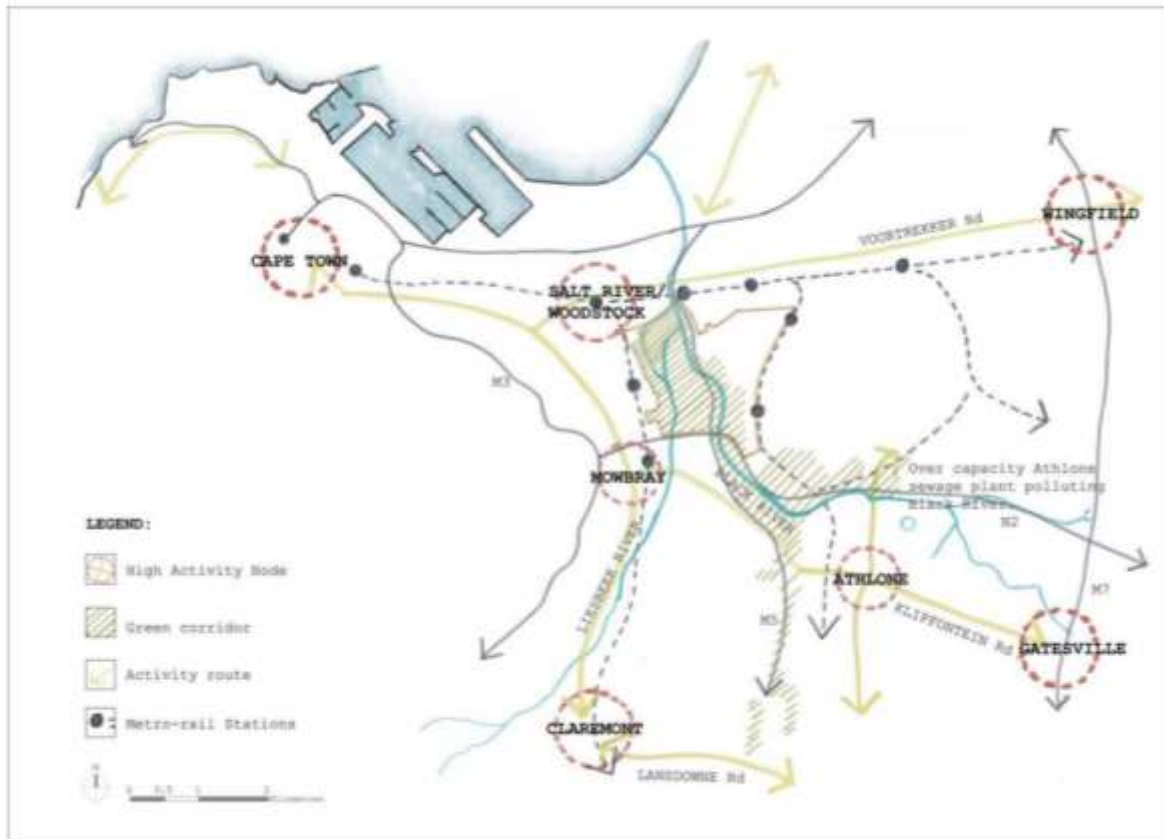


Figure 10: Location of the River Club in Relation to High Activity Nodes and Green Corridors within Cape Town (Gluckman & Lubbe, 2016)

The image above indicates the position of the River Club in relation to the city centre and other important nodes throughout the city. A spatial disconnect is created by the green corridor comprised predominantly of a series of wetland and riverine environments. These systems provide the opportunity for the residents of the city to have access to natural, green, open space and provide a host of ESS's pertinent to numerous social, economic and environmental functioning (De Groot *et al*, 2002). As such this green corridor plays an important role in Cape Town, the majority of which is formerly protected by the City . The corridor does however exacerbate the spatial disconnect within the city with limited transport routes, including road and rail, traversing this area.

Infrastructural Constraints

The River Club falls within the Table Bay District, one in which infrastructure is under substantial pressure, largely pertaining to constraints on the capacity of systems responsible for the reticulation and provision of bulk water services (CoCT, 2012). Infrastructure constraints are a major challenge within the district largely brought about by increasing densities and a growing population placing increased pressure on supply through increases in demand. The lack of capacity and constraints presented by existing infrastructure should be major considerations to be taken into account with the inception of new developments and throughout the development process. Infrastructure supporting

the delivery of bulk water services including reticulation and provision requires immediate attention, including systems responsible for the removal of wastewater (CoCT, 2012). The development of the River Club will require a combination of new and upgraded infrastructure within the Table Bay District and will require substantial financial resources from the local municipality. The Paarden Island Booster Pump will require upgrading to accommodate increased water supply, coupled with upgrading and installation of water supply pipelines. There are major challenges associated with the reticulation and treatment of wastewater as a result of the area's primary WWT plant, Athlone WWTW, currently operating over capacity and the ageing and limited capacity of existing sewer systems (CoCT, 2012). There is currently limited stormwater management infrastructure within the River Club, development of this site will require infrastructure to manage this water.

Existing municipal infrastructure is thus limited in its current capacity in accommodating stormwater management, increased demand for water supply and WWT (WCG, 2016). It is estimated that these systems have the capacity to supply 40% of the total requirements for the development of the River Club (WCG, 2016). The River Club must seek ways in which to reduce water demand and wastewater so as to relieve pressures on current municipal water resource management and associated infrastructure. The development must incorporate a multitude of social, economic and environmental concerns so as to promote sustainable development. It is proposed that much of the challenges and objectives discussed above can be achieved by applying the principles of WSUD within spatial planning



Figure 11: View Analysis of the River Club Site

The view analysis highlights a number of important features inherent to the River Club. Photograph A is indicative of the current lack of infrastructure currently present on the site and provides a northward

view demonstrating the current land-use. Photograph 'B' provides a westward view across the site indicating views of Devils Peak. A view of the Raapenberg Wetland looking over the constructed canal to the east of the site is provided by photograph C. Photograph D indicates the relationship between the site, the original channel of the Liesbeek River and Liesbeek Parkway, a road on the western boundary of the River Club. The highly degraded original channel of the Liesbeek River with Liesbeek Parkway to the left of the frame is depicted in photograph E.

Spatial Informants



Figure 12: Analysis of the Spatial Informants for the Development of a Spatial Plan

The contextual analysis has provided a number of spatial informants which must be taken into consideration in the creation of development plans for the River Club. The natural systems within and beyond the boundaries of the site are important natural features within Cape Town, as such these systems must not succumb to adverse effects of development. The plans for development should

include measures to protect and, where possible, restore riverine and wetland environments. These natural systems have created a spatial barrier between the western and eastern parts of Cape Town resulting in disconnect. Spatial plans must endeavour to promote increased connectivity throughout the city so as to create a more inclusive city. A more inclusive city requires the need for increased access to and opportunity for all regarding environmental resources, livelihoods, services and social amenities. The densification of the city provides a means to enable people to live closer to their place of work and is a preventative measure against urban sprawl. The need for a densified and inclusive city requires equitable access to a diverse array of socio-economic opportunities which can be facilitated through spatial planning. For example promoting various economic activities and housing options which enable both low and high income groups to reside in an area, thereby reducing spatial inequalities.

Applying WSUD Principles to Spatial Planning and Urban Design

Zoning

The River Club has been divided into four distinct zones so as to delineate water resource management areas and indicate the inherent interactions between these areas. Zone 1 comprises sub-surface water resources, bulk infrastructure development is categorised in Zone 2, Zone 3 is a 30 meter buffer zone between the river bank and major development designed to reduce negative impacts of development on riverine environments and Zones 4, to the west and east of the development, delineate the riverine environment.

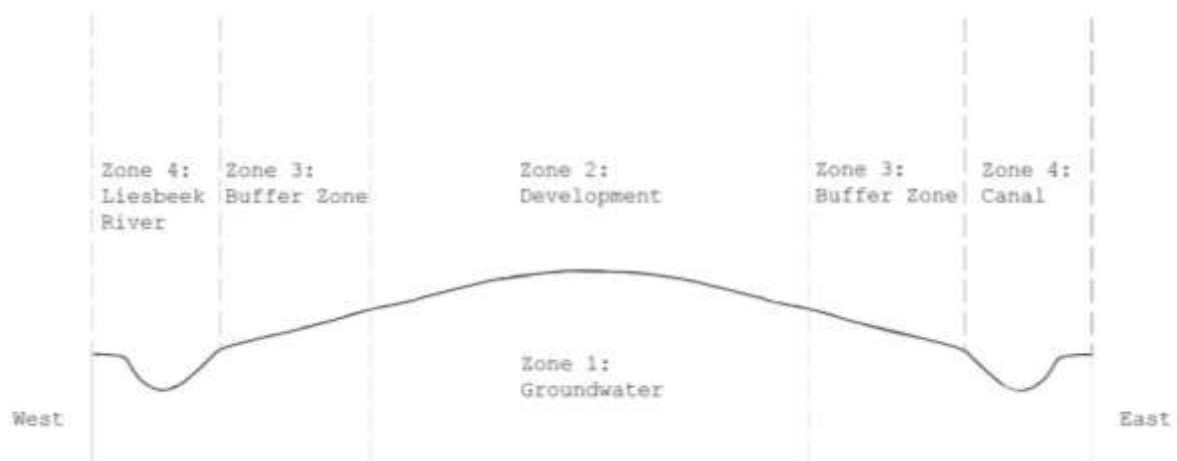


Figure 13: Cross-Section Illustrating the Various Zones of the River Club Site



Figure 14: Conceptual Diagram Delineating the Zones Identified within the River Club (Adapted from Gluckman & Lubbe, 2016)

Zone 1: Groundwater

Groundwater plays two fundamental supporting roles in urban water resource management. These are: the provision of water supply and reducing flood risk through receiving runoff via infiltration (Armitage *et al*, 2014). Groundwater, in its natural state, provides fundamental support to the functioning of natural systems however the sustainable abstraction and management of this resource has exhibited numerous economic, environmental and social benefits contributing significantly to sustainable development initiatives in cities around the world (Hiscock *et al*, 2002). The abstraction of groundwater in numerous developing countries has been recorded to facilitate rapid economic growth and development and improved human-health and well-being predominantly through enhanced service provision (Hiscock *et al*, 2002).

The quality of groundwater can be influenced by the infiltration of polluted surface water, leakages in infrastructural networks and a host of wastewater sources. The quality of groundwater determines what this resource can be utilised for in the context of supplementing municipal water supply. In addition to having potential negative impacts on the quality of groundwater resources, there are numerous infrastructural solutions which seek to protect the quality of this resource. Urban infrastructure can be utilised to dictate and manage groundwater quantity and quality through controlled infiltration of surface water, predominantly that accrued during high rainfall events. The management of groundwater is critical in that over abstraction can result in the lowering of ground levels and high rates of recharge enhance the risk of flooding (Armitage *et al*, 2014). As a result urban infrastructure has a significant impact on both the quality and quantity of urban groundwater resources.

It is important to consider the interactions between groundwater and surface water within the River Club given the high water table and the presence of rivers which border the site. Surface water recharges groundwater via infiltration whilst groundwater is critical to river systems in that it provides base-flow which is a supporting function of flow within riverine and wetland systems (Armitage *et al*, 2014). The high levels of interaction between groundwater and surface water are significant within the River Club development given the low water quality within the Liesbeek and Black Rivers. Concerns thus arise as to the quality of groundwater placing restrictions on the scope of its use as an alternative source of water supply.

Despite development plans to increase the elevation of the River Club site the high water table present within the region presents a number of risks with regard to flooding. The infiltration of stormwater runoff during high rainfall events can result in rapid saturation (the point at which infiltration is no

longer possible) and flooding ensues. Spatial planning must thus make provisions which seek to manage groundwater recharge in a manner which increases resilience by reducing flood risk.

The use of groundwater within the River Club development requires three major objectives; 1) prevention of pipe leakages of existing urban water infrastructure including wastewater, stormwater and potable water systems, 2) effective land-use planning and, 3) monitoring of groundwater quality and quantity (Armitage *et al*, 2014).

Groundwater Supply

Despite concerns with regard to the quality of groundwater within the River Club site, groundwater presents a number of opportunities as a source of water supply. It is proposed herein that this development utilises this resource for three major purposes; irrigation, firefighting and socio-economic upliftment.

The use of groundwater for irrigation purposes will enable the maintenance of landscapes so as to promote urban greenspace thereby facilitating greater urban bio-diversity and ecosystem functioning (Tratalos *et al*, 2007). Urban green space promotes environmental integrity resulting in the enhanced provision of multiple ESS's (Wolch *et al*, 2014). Numerous studies have indicated a direct correlation between the maintenance of urban green space and enhanced human health and well-being (Tzoulas *et al*, 2007). Wolch *et al* (2014) indicate that urban green space, "promotes physical activity, psychological well-being, and the general public health of urban residents"(Wolch *et al*, 2014:234). Urban greenspace can also promote increased public access to the River Club, facilitate increased accessibility, provide soft edges and facilitate non-motorised transport routes. In this manner, despite being a private development, the River Club can seek to promote greater levels of social integration, environmental integrity and human health through the provision of urban greenspace supported by a water sensitive approach. In addition, this resource can be used as a resource for firefighting strategies in reducing the potential threat of fires to property, the environment and human health.

The groundwater resources within the River Club provide an opportunity for socio-economic upliftment of local community members through the provision of sustainable water intensive business opportunities. It is proposed that groundwater be utilised as a resource to facilitate a car wash service within the development. The site currently facilitates a car wash service thus this intervention will enable current employees to retain their jobs and provide additional economic opportunities for local community members.

Groundwater Infiltration

As mentioned the high water table in the River Club presents a potential hazard for high rates of infiltration. This must be incorporated into flood risk management as a measure to increase resilience.

Surface water accumulated from high rainfall events must be effectively managed so as to control groundwater infiltration and, by extension, flood risk. Spatial, infrastructural and management solutions pertaining to groundwater infiltration are discussed in greater detail in the interventions for Zone 2.

Infrastructure

The major infrastructural components to support groundwater harvesting and the interventions suggested herein are a borehole, water storage tanks and a piped network. Boreholes provide a means to abstract groundwater delivering this water resource to the surface level. It is proposed that this water is collected in water tanks from where it is transported throughout the development via a piped network. On-site management and monitoring systems are vital to preventing negative outcomes from groundwater abstraction.

Zone 2: Major Infrastructural Development

Stormwater Management

The inadequate management of stormwater poses a significant threat to urban infrastructure and human health and well-being. Stormwater management in Cape Town, as previously noted, has treated this resource largely as a nuisance, seeking its rapid removal from the urban landscape. High pollution rates of stormwater runoff and the realisation of the intrinsic value of this resource are beginning to alter the approaches to the management of this water (Wong & Eadie, 2000). Adaptive management approaches are incorporating concerns of the quality of stormwater runoff and recognising the benefits of capturing this resource in resilience planning which extends beyond the protection of urban infrastructure. A transformative approach to stormwater management is required in the way in which urban areas are planned and designed. This requires current urban form and development patterns to be altered in a manner which promotes water sensitive environments (Wong & Eadie, 2000).

As a result of the dynamics of the urban water cycle, SuDS has been proposed as a means in which to manage the drainage systems of urban areas under the WSUD approach (Armitage *et al*, 2014). The diagram below provides a summary of the infrastructural options available within the WSUD approach.

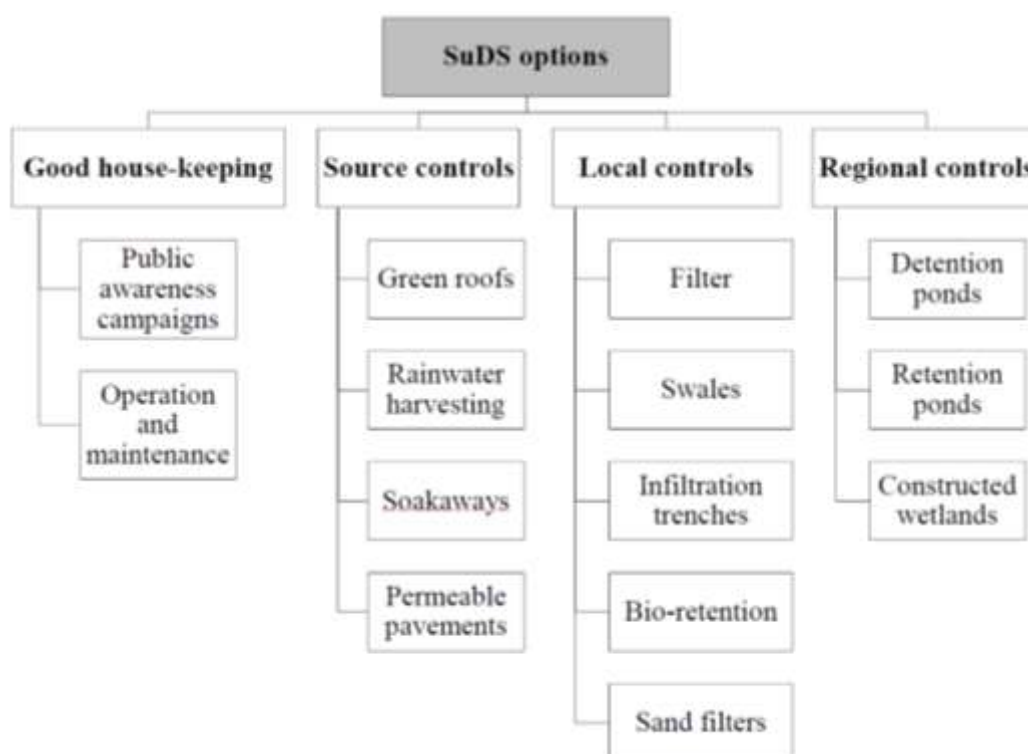


Figure 15: Summary of SuDS Options (Armitage *et al*, 2014:53)

The site must be assessed in terms of a number of criteria which include current land-use, projected changes in land use, environmental considerations, the characteristics of the site and of the catchment

at large (Armitage *et al*, 2014). It is important to note that despite numerous SuDS infrastructural and stormwater management options the application of all of these options on a single site is highly unlikely (Armitage *et al*, 2014).

The contextual analysis indicates that the River Club site is highly susceptible to the risk of flooding however there has been little need for extensive stormwater management largely as a result of little infrastructural investment. There is thus little to no stormwater drainage infrastructure currently present on the site which experiences periodic flooding. Proposals for land-use change which include increased interest in infrastructural development to accommodate residential and commercial land-use activities have resulted in the need to raise the elevation of the site above the 1:100 year flood line. These modifications and development plans require enhanced stormwater management on the site. In accordance with SuDS the approach to the management of stormwater on the site must consider possible negative effects on the natural environment especially the sensitive aquatic systems which surround the site. The contamination and subsequent reduced water quality of stormwater runoff commonly associated with urban areas can have negative impacts on ecological, riverine, wetland and groundwater systems.

The location of the River Club site on the floodplain of the Liesbeek and Black Rivers makes it highly susceptible to the risk of flooding despite the raising of the ground level as per the current development plans. The location of the site at the lower end of the Salt River Catchment and the high water table present a number of challenges with regard to the management of flood risk. It is proposed that a SuDS approach be taken to the management of stormwater in the site in a manner which reflects water as a valuable resource and serves to promote sustainable development in accordance with WSUD. A number of infrastructural, spatial planning and urban design interventions and solutions to ensure the effective and efficient management of stormwater and the promotion of sustainable development within the River Club are presented below.

Green Roofs

The destruction of natural systems as a result of continual expansion of urban areas has resulted in the need to incorporate innovative solutions within the urban fabric to promote environmental health and integrity (Mentens *et al*, 2006). In addition, alterations in land-use have had a significant impact on local hydrological functioning. Increases in stormwater runoff, largely due to reduced infiltration capacity, are largely a product of impermeable surfaces. Runoff generated during high rainfall events is thus intensified placing pressure on existing stormwater infrastructure and increasing threats to infrastructure and human lives (Mentens *et al*, 2006).

Green roofs provide a solution to numerous stormwater and environmental management issues inherent to urban areas (Mentens *et al*, 2006). These roofs, which are essentially roof top gardens, provide a number of ESSs and supportive functions addressing issues pertaining to food security, urban biodiversity, stormwater management, urban heat islands and sustainable development simultaneously. Green roofs have the capacity to reduce stormwater runoff by absorption, retention, use and slow release (Mentens *et al*, 2006). Green roofs increase albedo, which is the reflective capacity of a surface, thereby reducing heat storage and contributing to the reduction of the urban heat island effect (Takebayashi & Moriyama, 2007). Plants facilitate increased carbon sequestration and promote increased urban biodiversity through species diversity (Schrader & Böning, 2006). As a result of these benefits, and numerous others, green roofs exhibit the capacity to contribute greatly to sustainable development (Getter & Rowe, 2006).

It is proposed herein that the River Club adopt green roofs as a stormwater management approach. Green roofs are proposed as a strategy through which to promote social upliftment to low income groups within TRUP providing a multi-purpose solution to stormwater management. The green roof initiative can be utilised to provide jobs to local community members and improve food security within the area. Productive crops can be grown on roof tops and sold in a local market. The profits of this economic activity can be used to subsidise salaries and the instillation and upkeep costs associated with the initiative. Green roofs can thus support socio-economic opportunities through job creation, provision of a market space within the development and in time can become a self-supporting system. The provision of a market space within the development can include the selling of other local produce i.e. produce from Oudemolon, an ecovillage within TRUP. In addition to the benefits of green roofs discussed above the development can promote higher social integration and economic upliftment. In times of low rainfall groundwater can supplement water requirements for maintaining the gardens. Excess water is drained into a rainwater tank as discussed in the section detailing stormwater harvesting.

Durban, South Africa

A number of cities around the world, including Durban, are utilizing productive green roofs and urban agriculture as a means to manage stormwater and mitigate against climate change (Dubbeling, 2014). Studies on green roofs in Durban have produced results which indicate that these systems have a significant impact on reducing the urban heat island. Air temperatures above roof tops were recorded to be an average temperature of approximately 20 degrees celsius lower above green roofs in comparison to unvegetated rooftops (Dubbeling & Massonneau, 2014). A study which examined the effectiveness of green roofs in managing stormwater run-off in Durban indicated that vegetated rooftops produced eight times less run-off in comparison to unvegetated rooftops of the same size (Dubbeling & Massonneau, 2014). Similar results have been recorded in relation to the ability of these rooftop systems to support and promote increased biodiversity (Dubbeling & Massonneau, 2014). City has begun to adapt productive roofs, this recent strategy development will require monitoring to determine its effectiveness. Toronto, Canada, has demonstrated the supportive capacity of green roofs for urban agricultural production. Green roofs can take numerous forms of formality from highly organized systems in the global north to forms which exhibit informality and low levels of coordinated organization in the global south. The images below provide an example of the differing levels of formality green roofs can take.



(Left) Toronto, Canada, Green roof (Dubbeling & Massonneau, 2014:28)

(Right) Kathmandu, Nepal, Green Roof (Dubbeling & Massonneau, 2014:31)

Figure 16: Local and International Precedence for Green Roofs

Stormwater Harvesting

The harvesting of stormwater involves, “the collection, treatment, storage and use of stormwater runoff from urban areas”(DECNSW, 2006:2). As a result, stormwater harvesting presents an opportunity for alternative provision of water supply within an urban area. This measure enables the combination of water supply and stormwater management to increase resource efficiency (Armitage *et al*, 2014). Infrastructure and design interventions thus serve a dual purpose reducing cost and building resilience through simultaneously lowering flood risk and increasing water resource provision.

It is proposed that the River Club development utilise tanks to collect and store stormwater resources. Given the limited capacity of rainwater tanks it is suggested that these tanks be installed to collect water

accrued from rooftops during rainfall events. Rainwater tanks provide a water supply source which has the capacity to supplement municipal water supply (Khastagir & Jayasuriya, 2010). The system proposed is a decentralised system to be installed in individual buildings capturing rainwater from rooftops and delivering it to tanks for storage via a piped network. These tanks store water and provide an alternative potable water resource to be used for a combination of amenities including consumption, personal hygiene and water intensive appliances such as washing machines. Water to be used for potable purposes is to flow through a filtration system before being consumed. Superimposing this system with municipal potable water supply will enable the reduction of pressure on municipal infrastructure and service delivery. Switching between the systems on an 'as needed' basis promotes water savings and rainwater tanks serve a dual purpose incorporating water collection and storage with stormwater management. Excess stormwater collected during heavy or prolonged rainfall events, which result in the overflow of rainwater tanks, will flow from these tanks into Zone 3. The details of the management of this excess water are dealt with in infrastructural solutions for Zone 3.

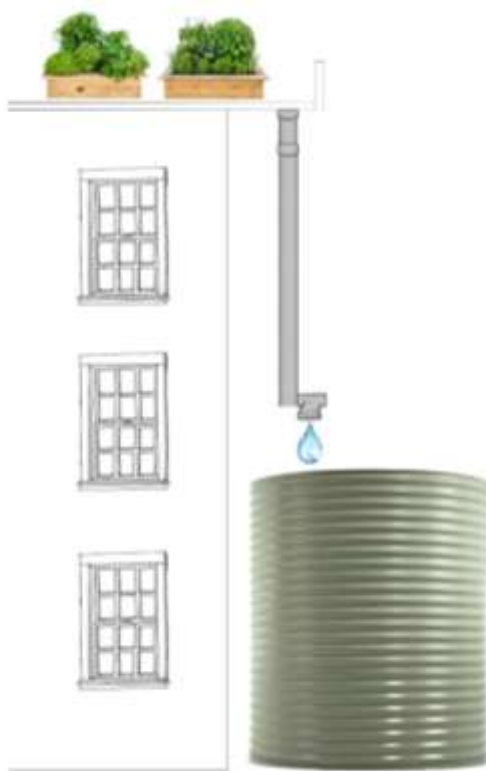


Figure 17: Conceptual Model for Rooftop Stormwater Harvesting

The high water table and high risk of flooding within the development, calls for innovative solutions for the removal of stormwater in a manner which prevents environmental harm from low quality runoff and damage to local infrastructure. As a result of a high water table water storage tanks cannot be located below ground thus the ability to store stormwater on-site is limited. The management of surface runoff thus requires innovative solutions as illustrated by the stormwater harvesting examples below.

New South Wales, Australia

Rainwater Harvesting using rainwater tanks has recorded international success in both developed and developing countries. Eroksuz & Rahman (2010) undertook a study of a site with a total area of 4000m squared in New South Wales, Australia to determine potential water savings through the use of rainwater tanks. The site, which houses approximately 70 residents, collects rooftop rainwater in rainwater tanks from a total roof coverage of 2000 square meters. Water from these tanks was used for a combination of irrigation, laundry, flushing toilets and hot water (Eroksuz & Rahman, 2010). The study found that a tank with a capacity of 10 kiloliters recorded a reduced reliance on water mains by 21% (Eroksuz & Rahman, 2010). Rainwater tanks thus have the capacity to reduce pressure on municipal water supply.

Figure 18: Stormwater Harvesting - Australia

Uganda

Baguma & Loiskandl (2010) considered the application of rainwater harvesting in Uganda as a means to build resilience against water shortages. The study focused on poor communities who lacked adequate governmental service provision and experienced regular water shortages. The report suggests that, when subsidized, the adoption of rainwater harvesting technologies among poor communities was successful despite variances in household income, age or level of education (Baguma & Loiskandl, 2010). Rainwater harvesting was shown to be an effective means to promote poverty alleviation through the provision of safe drinking water and improved overall hygiene (Baguma & Loiskandl, 2010). Rainwater tanks thus provide a measure for both low (when subsidized) and high income groups to increase resilience against water supply shortages and reduce pressures on municipal water supply.

Figure 19: Stormwater Harvesting - Uganda

Dhaka, Bangladesh

Safe drinking water shortages are a common feature in Bangladesh as a result of annual monsoons (Islam et al, 2010). In addition, numerous urban areas including the countries capital city, Dhaka, have limited capacity to meet demands for potable water. Islam et al (2010) considered rainwater harvesting as a solution to improving access to potable water and building resilience amongst communities during the monsoon season. Focusing predominantly on the urban poor, rainwater harvesting, utilizing traditional filtration systems, was found to improve accessibility to safe drinking water (Islam et al, 2010). This study indicates the benefits of rainwater harvesting in the provision of safe drinking water and the ability to implement these systems among the urban poor of a developing country.

Figure 20: Stormwater Harvesting - Bangladesh

Surface Drainage Systems

Roads are sources of numerous chemical contaminants accrued from motor vehicles (Brown & Peake, 2006). These contaminants, which include polycyclic aromatic hydrocarbons and a variety of heavy metals, are collected by stormwater runoff during high rainfall events and, as per current stormwater management approaches in Cape Town, discharged into natural environments (Brown & Peake, 2006). These contaminants present a significant threat to the natural environment and human health and well-being. As a result, strategies must be implemented to improve the quality of stormwater runoff.

WSUD promotes permeable urban surfaces as a green infrastructure solution to increase rates of infiltration and reduce stormwater runoff. The high water table present on the River Club site presents two major drawbacks with regard to permeable surfaces in terms of increased risk of flooding and groundwater contamination. A high water table reduces infiltration capacity as soil becomes saturated more rapidly increasing the flood risk. During the infiltration process water quality is improved by means of filtration and a high water table reduces the capacity for sub-surface filtration thus increasing the risk of groundwater contamination. Although open space throughout the development will consist largely of permeable surfaces these areas present significantly less risk for groundwater contamination in comparison to road surfaces.

It is thus proposed that road surfaces consist of impermeable surfaces which collect and channel stormwater runoff to the roadside. A soft edge consisting of semi-permeable drains is to be constructed alongside roads serving as a soft barrier between roads and pedestrian walkways and as a means to manage stormwater. These open drains are to be composed of a gravel zone with an impermeable bottom to contain water and deliver it to Zone 3. The gravel is to be vegetated so as to allow for the system to polish stormwater as it moves to Zone 3. The drains should facilitate gravitational flow and form an interconnected system. These drains will reduce flood risk, increase quality of stormwater

runoff and prevent the risk of stormwater contamination by municipal infrastructural systems including sewerage pipes. In addition, roadside drainage features will increase legibility for motorised and non-motorised transport by providing a soft edge between the road and NMT routes.

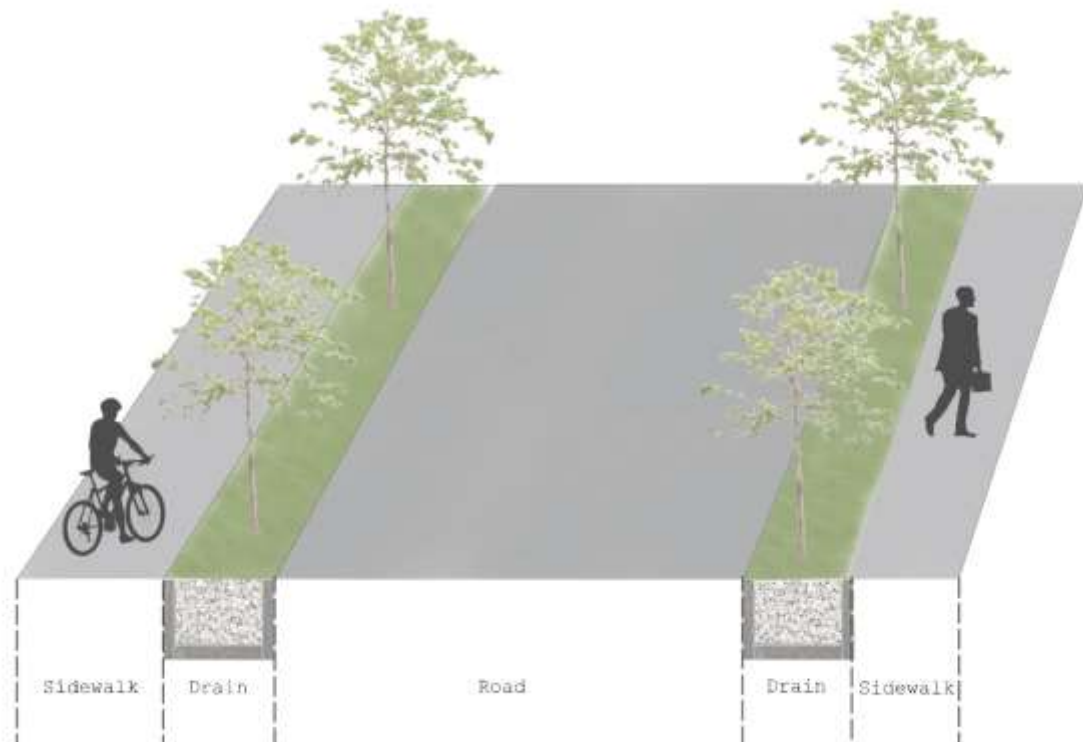


Figure 21: Model Depicting Ideas for the Drainage of Roads and Sidewalks

Impermeable road and sidewalk surfaces channel stormwater into roadside drainage systems. These systems should be constructed of impermeable materials to retain water and deliver it to constructed wetland systems in Zone 3. Gravel and vegetation within these systems provide filtration services removing pollutants from stormwater and, as a result, improve the water quality of this resource. These vegetated drainage systems serve a secondary function of increased legibility by delineating motorised and NMT routes.

Greywater Re-Use

The re-use of greywater presents a risk for environmental health and human well-being as it can contain potentially hazardous substances. The release of greywater into natural systems or for re-use as potable water thus requires the treatment of this water. The effective treatment of this water often requires a combination of treatment methods which can be extremely costly (Pidou *et al*, 2007). The extensive nature and cost associated with on-site greywater treatment presents a number of challenges particularly within an urban area of a developing country where financial resources and space are limited.

Greywater recycling is thus not recognised as a viable option for the River Club site however It is proposed that the development incorporate a greywater re-use initiative. The re-use system proposed requires buildings to install infrastructure which collects greywater on a separate system, passes it through a simple filtration system and stores this water in holding tanks. This water can then be utilised for flushing toilets reducing the use of municipal potable water supply and reducing wastewater generation. The examples below indicate the potential for water savings presented by the re-use of greywater.

Mallorca, Spain & Florianopolis, Brazil

A study conducted on the potential for water savings by using greywater as a resource for flushing toilets was conducted in a hotel in Mallorca, Spain. The results indicated that a total of 23% of the hotels water was re-used representing massive water saving potential for re-use in toilets (March & Orozco, 2004). Three residential buildings in Florianopolis, Brazil, were considered in a study to determine the effectiveness of reusing greywater to flush toilets. It was found that greywater collection between the buildings provided an adequate supply for toilet flushing requirements presenting an opportunity for considerable water savings (Ghisi & Ferreira, 2007).

Figure 22: Greywater Re-Use - Spain and Brazil

Zone 3: Buffer Zone

Zone 3 is proposed as a buffer zone between infrastructure development and the riverine environment largely as a means to prevent environmental degradation and reduce flood risk within the development. This zone has the capacity to address a number of spatial planning and urban design features to promote accessibility to the site, enhance mobility through the site, enhance liveability, enhance natural systems and reduce the potentially exclusive nature of the development. The green infrastructure proposed for this zone thus serves multiple functions and contributes significantly to promoting sustainable development within the River Club site.

Constructed wetlands provide a system through which to improve the quality of stormwater runoff and various sources of wastewater. Enhancing the quality of this water promotes safe discharge into natural systems reducing the negative impacts of urban areas on the natural environment. These systems present relatively low costs associated with construction and require low levels of maintenance (Shutes, 2001). Sub-surface flow artificial wetlands are proposed for Zone 3 of the River Club Site to ensure that stormwater runoff and overflow from rainwater tanks are treated to a level which does not pose a threat to the natural environment. Sub-surface flow wetlands consist of a variety of vegetated media including rocks and gravel which facilitate the vertical and horizontal flow of water through the system (Shutes, 2001; Vymazal, 2010). This form of artificial wetlands enables maximum contact between the water and the plant and substrate matter which enhances the purification process (Shutes, 2001). The longevity of these systems coupled with their aesthetic appeal and environmental benefits make them an attractive and cost effective option for the treatment of stormwater within a development (Shutes, 2001).

It is proposed that these systems be installed intermittently, as required, within Zone 3 incorporating NMT movement systems through this zone, promoting high quality open space and providing a soft urban edge between public and private land.

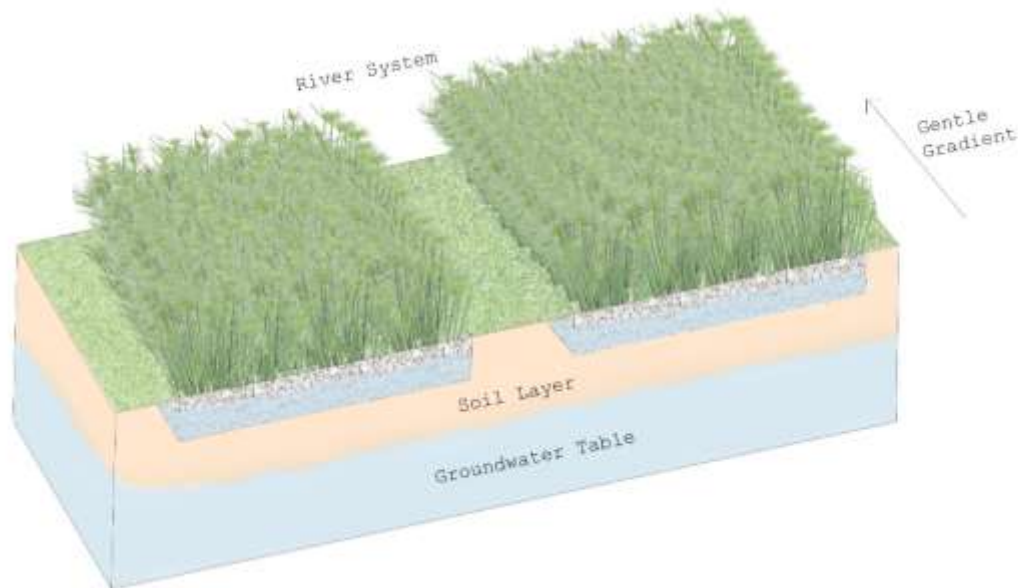


Figure 23: Model of Proposed Artificial Wetlands

Water enters the wetland via drainage systems within the development and flows down a gentle gradient toward the river system. The longer the residence time of water within the wetland the greater the impact of the system in improving water quality. Note that there is no interaction between the system and groundwater. Key to the optimal functioning of the constructed wetlands is ensuring that the systems are constructed of impermeable materials designed to retain water in an isolated and controlled manner. The use of artificial wetlands in improving water quality and enhancing green open space is considered in the example of Putrajaya below.

Putrajaya, Malaysia

Artificial wetlands have been utilized in a development in Putrajaya, Malaysia, as a strategy to improve the quality of green open space. A lake, one of the constructed water features central to the green open space network, receives water from the polluted Chuau River (Shutes, 2001; Sim et al, 2007). A series of artificial wetlands are used to treat and filter polluted river water before it enters the lake and other water bodies within the development. In addition to improving the water quality these wetland systems enhance local ecological functioning and provide high quality open space networks with high aesthetic appeal for local residents (Shutes, 2001).

Figure 24: Artificial Wetlands - Malaysia

Zone 4: Riverine & Wetland Environments

Urban rivers possess the capacity to provide numerous social, economic and environmental benefits to an urban area (Findlay & Taylor, 2006; Francis, 2012). Urbanisation and activities inherent to the urban landscape result in the degradation of these systems jeopardising their ability to provide these benefits (Findlay & Taylor, 2006).



Figure 25: Map Locating Areas of Focus within Zone 4 (Adapted From Gluckman & Lubbe, 2016)

Zone 4 is comprised of two riverine environments that border the River Club site: the original Liesbeek River Channel to the west and the canalised system to the east. The man-made canal system to the east was constructed as a means to enhance the removal of stormwater downstream of the Liesbeek River in an attempt to rapidly remove this water and reduce the risk of flooding. Although WSUD advocates the retention and use of stormwater the spatial and cost implications currently limit this approach. There is limited space for retention and storage of stormwater within this zone given its close proximity to the ocean and the need for densification within Cape Town. The Raapenberg Wetland System, however, does provide an ESS of natural water retention in the area. Retention and storage of river water is proposed as an upstream (off-site) intervention that, it is hoped, will be catalysed by WSUD interventions within the River Club site. The promotion of these interventions upstream will promote the SuDS approach to stormwater management and the improvement of water quality through a treatment train approach along the stream channel.

The high costs, relative to the current benefits, of restoring this canal to a natural state are herein deemed unnecessary as this system still contributes significantly to relieving pressures on other conventional stormwater infrastructure in the local area. The scope for utilising this space as a means to enhance public open space is limited given its location between the River Club and the Raapenberg Bird Sanctuary. Zone 3, on the eastern boundary provides features which promote NMT movement, enhance the aesthetics and improve environmental conditions within this area.

The original Liesbeek River Channel is currently highly degraded as indicated in the analysis, providing little support to local ecological functioning and stormwater management. Spatially, this river system presents a number of opportunities to make positive contributions to the local area. It is currently located along a public road (Liesbeek Parkway) and forms part of an ecological corridor which the local municipality has sought to promote through the provision of landscaping interventions and NMT routes along this corridor. The river presents an opportunity for a soft, natural, boundary between the public and private domain. It also presents opportunities for enhanced public open space, supportive functions for stormwater management and ecological supportive functions.

The rehabilitation of river systems within an urban area, present opportunities to enhance local social, economic and environmental conditions (Findlay & Taylor, 2006). It is thus proposed that the original channel of the Liesbeek River be restored in a manner which targets the achievement of these opportunities. It is proposed that programmes such as Working for Water be enlisted to remove alien vegetation from the stream channel and river banks and that indigenous aquatic plants be planted as a strategy to enhance water quality by removing pollutants accrued from upstream sources. Initiatives such as the Friends of the Liesbeek River currently contribute significantly to restoring vast sections of

the Liesbeek River in an endeavour to increase the health of this system. It is hoped that restoring the environmental integrity of the original channel of this river will serve as a catalyst for greater interests upstream in interventions which reduce river water contamination and contribute the improvement of water quality within the stream channel. Restoring the ecological functioning of this channel will enhance its capacity to contribute to the management of high riverine flows during excessive rainfall events. The location of this section of the river in the lower reaches of the Salt River Catchment results in periodically high flows during rainfall events throughout the catchment. The channel should therefore be able to cope with high flows and in so doing reduce the risk of flooding on the River Club site. The restoration efforts should also seek to promote the banks, particularly the west bank, as valuable public open space further enhancing the green corridor. This will contribute to enhancing mobility through the provision of NMT routes and increased legibility in the division of public and private space without necessitating intrusive physical boundaries. The connections between green, public open space and the improvement of human health and well-being are well documented thus the restoration of this river channel achieves numerous social and environmental objectives (Tzoulas *et al*, 2007). Singapore is an example of a city which has restored its urban rivers to enhance green open space throughout the city as indicated by the example below.

Singapore

Singapore has, recent years, sought to rehabilitate and reclaim the city's river systems to enhance social and environmental conditions within the city. "Derelict waterfronts and historic neighborhoods have been given new life, enjoying their reincarnation as landscapes of creativity, leisure and entertainment" (Chang & Huang, 2011:2086) through spatial planning strategies in Singapore. The reclamation of the cities rivers focused on the functional uses of the land, enhanced public accessibility and a heightened 'sense of place' for local residents (Chang & Huang, 2011). Singapore's achievements in enhancing social identity, improving the aesthetics of public open space and creating a 'sense of place' through spatial planning and urban design initiatives serves as valuable precedence for what can be achieved in restoring the Liesbeek River. The findings of Chang & Huang (2011) suggest that one major flaw in Singapore's planning was the lack of attention in utilizing this space as a strategy to improve connectivity and mobility through NMT and motorized transport networks. It has thus been proposed that these measures are taken into consideration so as to achieve the full array of predominantly social and environmental benefits from riverine restoration.



Kallang River, Singapore. (Landezine.com)

Figure 26: Riverine Public Open Space - Singapore

WSUD Informants for Spatial Planning and Urban Design

WSUD, in addition to promoting sustainable development within the River Club, informs spatial planning and urban design and, in so doing, demonstrates an ability to enhance spatial plans. Strategies to protect and restore natural water courses are provided by WSUD which offer spatial solutions for improving water quality and preventing negative environmental impacts of development. Restoring the original channel of the Liesbeek River has implications for spatial planning in that, an opportunity is provided, for enhanced NMT mobility and connectivity and the provision of a combination of public and semi-private open space. This increased connectivity and the attraction of higher use by members of the public presents an opportunity for the promotion of mixed-use development along these corridors presenting a need for both commercial and residential development. The buffer zones, which comprise the bulk of this open space and facilitate enhanced NMT movement, inform the orientation of buildings within the development, promoting them to face outward providing views onto these areas. A grid street pattern facilitates enhanced stormwater drainage and is an enabler of the stormwater management approach herein presented. A decrease in elevation east and west from a central point through the development is an additional measure which facilitates enhanced stormwater drainage. These spatial informants are incorporated into the design of a conceptual SDF which represents a working spatial plan option for the development of the River Club.

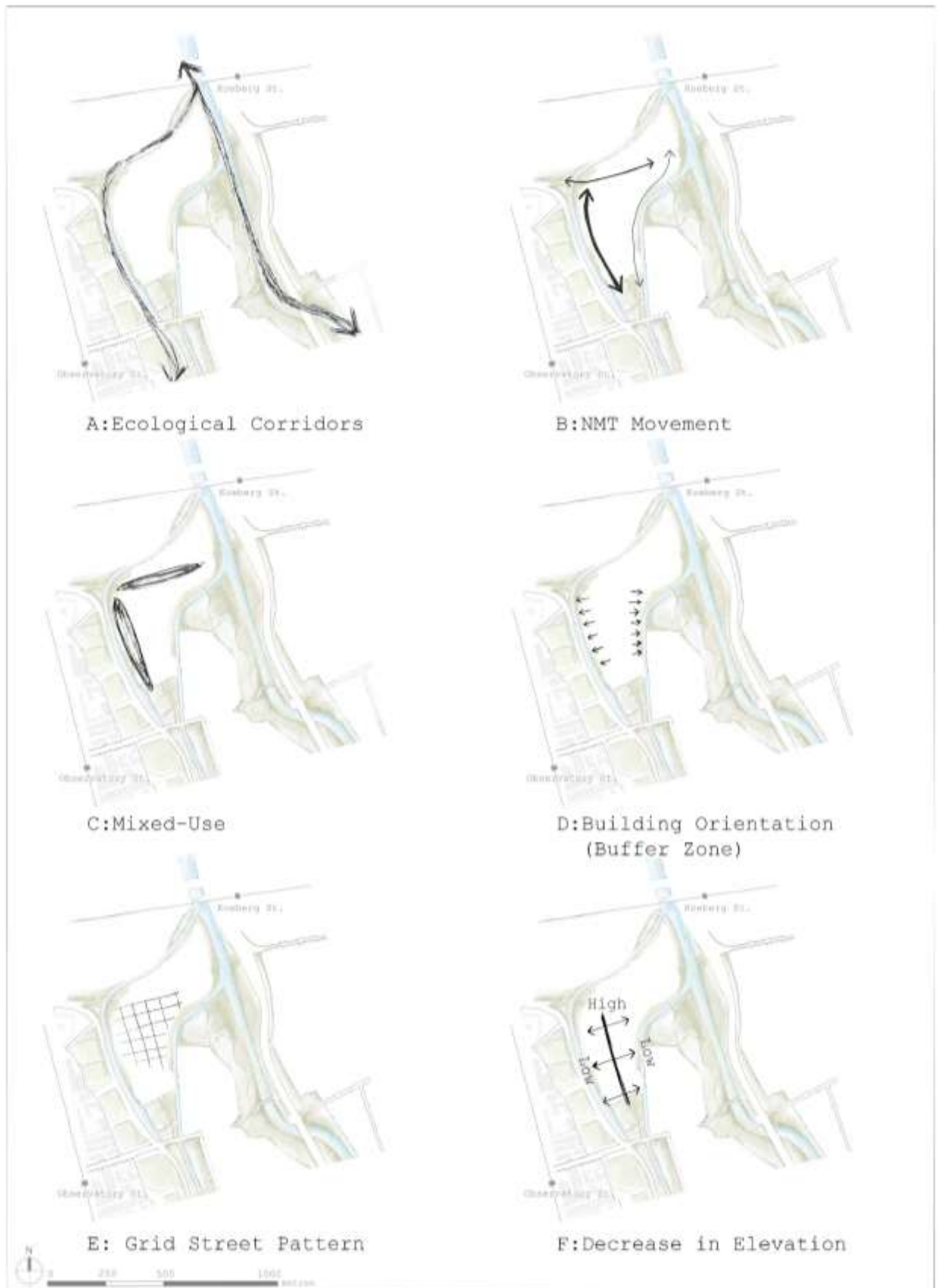


Figure 27: Spatial Informants Identified from Incorporating WSUD Principles

The conceptual SDF takes the spatial informants provided in the contextual analysis and WSUD recommendations to create a proposed development plan. This is regarded as a conceptual model as the analysis provided is insufficient in creating a comprehensive and final plan. Additional analysis, research, interdisciplinarity and public participatory processes will be required to create a comprehensive and final development plan. The plan presented herein is designed to serve as an idea generator; one which highlights a number of spatial interventions and recommendations to enable a development that meets a range of spatial objectives promoted by the City and promotes sustainable development through WSUD. In essence, this SDF serves as an example of the linkage between spatial planning and WSUD and the ability of spatial planning to promote this approach to water management.



Figure 28: Conceptual SDF for the River Club (Adapted From Gluckman & Lubbe, 2016)

The SDF provides a west-east linkage through the extension of Berkley Road from Maitland to the east to Liesbeek Parkway to the west of the site. A north-south linkage is provided connecting Observatory Road with the proposed Berkley Road extension. Development is set-back from the riverine environments by the provision of a buffer zone along the western and eastern development boundaries.



Figure 29: Depiction of the Grid Street Layout within the Conceptual SDF (Adapted from Gluckman & Lubbe, 2016)

The grid street pattern is proposed to facilitate WSUD stormwater drainage interventions allowing for enhanced drainage of streets and sidewalks and the delivery of this water into artificial wetlands in zone 3 on the peripheries of the development. This street pattern is not unconventional and is used within many cities to facilitate municipal infrastructure in service provision. In addition, grid street patterns serve as a measure to enhance legibility for those navigating the precinct.



Figure 30: Depiction of Motorised and NMT Connectivity and Movement Structures within and Beyond the River Club (Adapted from Gluckman & Lubbe, 2016)

As indicated a west-east connection is provided by the extension of Berkley Road with a proposed road connecting this extension in the north to Observatory Road in the south. The point where these roads meet provides a potential activity node for possible public transport stops and heightened commercial and retail activity. The extended Berkley Road is expected to be a major movement corridor and measures should be taken to prevent the north-south link from becoming a thoroughfare. Preventative measures could include speed control mechanisms such as speed bumps and traffic lights. These corridors should facilitate NMT movement within and through the development. The buffer zones to

the west and east provide opportunity for increased NMT movement which includes recreational and leisure activities such as running, walking and cycling. They also serve to promote enhanced connectivity for those utilising NMT as a primary mode of transport. As a result these corridors should make provisions for a wide variety of NMT movement and artificial wetlands designed in a way which does not jeopardise the functioning of either system.



Figure 31: Conceptual Plan Grouping Buildings Based on Use and Height (Adapted from Gluckman & Lubbe, 2016)

Buildings marked A are located in areas which enable mixed-use as they are situated along prominent movement corridors. These buildings should facilitate commercial and retail activity on the ground floor with mixed residential and commercial on the floors above. Commercial and retail activity on the ground floor provides easy access for those utilising Berkley Road as a movement corridor. Buildings to the west along the original channel of the Liesbeek River should enhance and frame the public and semi-private open space by providing commercial and retail activities including restaurants and coffee shops on the ground floor. The orientation of these buildings to face the public open space and the street scape is a design strategy to improve safety and security in these areas through increased surveillance by the occupants of these buildings. The buildings along the western boundary should display semi-private façades to the west (as depicted in the figure below) while the east of the buildings should accommodate private use. These buildings should not exceed two stories so as to maintain mountain views for buildings to the east. The north facing buildings along Berkley Road, although along a high activity corridor, should not exceed two stories to negate blocking sunlight from buildings to the south.

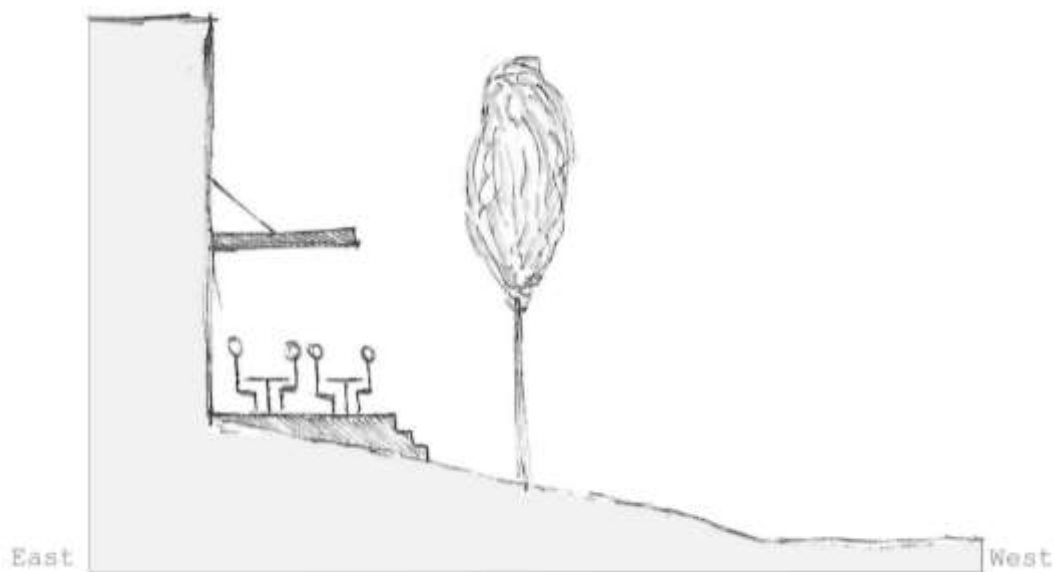


Figure 32: Cross-Section (E-E) Indicating Building Interface with Public Space

Buildings in area B should accommodate a wide array of economic activities and facilitate residential usage. These buildings are located in close proximity to Berkley Road and potential public transport interchanges thus are easily accessible for employees and those wishing to access services who do not reside within the development. These buildings, given their primary function, are larger in surface area however should not exceed heights of three stories.

Area C should make provisions for a wide variety of residential units enabling a mixture of income groups to reside within the development. As a densification strategy multi-story buildings, which do not exceed four stories, are promoted. These buildings should accommodate a variety of uses with residential as the primary use. Buildings along the eastern boundary should be designed to face the open space created by the buffer zone to enhance safety and security in this area. In addition, the Raapenberg Wetland and Bird Sanctuary provide aesthetic appeal and views for local residents.

The southernmost building within the development is an existing building with heritage significance. It is proposed that buildings marked within area D frame this building creating a public square which could facilitate numerous activities. These buildings are promoted to accommodate a mix of commercial, retail and civic uses along with recreational facilities to enhance the live, work, play nature of the development.

It is proposed that the open space to the south contain a mixture of soft and semi-permanent infrastructure to facilitate open space and make provisions for a market. The provision of a market will provide economic opportunities for informal traders and for the trade of produce produced on the green roofs and at the Oudemolon Ecovillage to the east of the River Club.

This conceptual SDF has indicated the ability to incorporate WSUD with numerous spatial principles and CoCT objectives in the creation of a SDP. For example, WSUD enables higher population densities as it reduces pressures on municipal infrastructure enabling greater carrying capacity within areas characterised by inadequate infrastructure and service provision. Furthermore, WSUD has provided numerous spatial informants which have influenced the shaping of this development. The influence of WSUD goes beyond spatial. Applying the principles of this water management approach highlights the potential of the approach to promote sustainable development, through interventions and infrastructure which address a range of economic, social and environmental factors.

Urban Metabolism

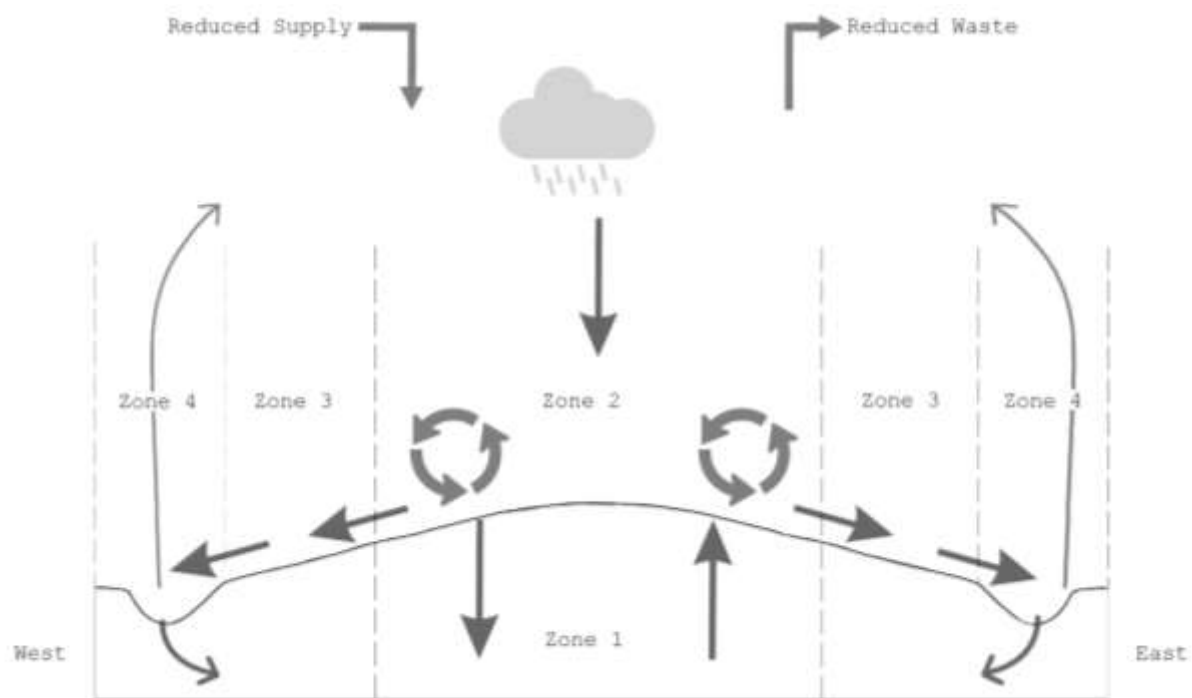


Figure 33: Conceptual Cross-Section of the Metabolic Activities of the Movement of Water Resources Into, Within and Out of The River Club

WSUD creates conditions in which the metabolic activities and processes of water within a defined space are enhanced. Focusing on a system which endorses sustainability is essential to enhance the self-sufficiency of a development or an entire city. This is a fundamental requirement in the promotion of a sustainable city or settlement. Urban metabolisms rely on inputs of energy and generate outputs termed waste, WSUD, as indicated herein, exhibits the capacity to manipulate the metabolism of a system through various infrastructural and management interventions. The manipulation of the flows of water into, within and out of a development is a measure which can be utilised to increase the sustainability of the development in terms of reducing negative environmental outcomes, promoting human health and well-being and supporting economic growth and development. These sustainable development outcomes are significant in that they traverse the boundaries of the River Club development providing environmental benefits adjacent to the site and downstream, including municipal water savings and reduced dependencies on municipal infrastructure. These benefits create

conditions for the redirection and distribution of state financial and water resources to promote economic, social and environmental development elsewhere.

The proposals made herein seek to enhance the metabolism of water resources within the proposed development for the River Club in a manner which, among the factors discussed above, reduces water supply and the generation of wastewater. These two factors are the primary benefits of WSUD in this development given limited water resources in Cape Town and the limitations presented by water supply and the WWT infrastructure. WSUD enables this through the provision of private infrastructure within the development designed to harvest rainwater, efficiently manage stormwater, utilise groundwater resources and, among others, re-use greywater. Appropriate infrastructure and management strategies are key to the successful manipulation of water metabolisms.

A wide variety of infrastructural solutions are provided by WSUD which vary in size and cost allowing for a range of choice in types, combinations and spatial influence of this infrastructure. Infrastructural solutions, for example rainwater tanks, can be used in isolation of other WSUD infrastructure as a measure to enhance resilience and manipulate local water metabolisms. As a result the principles of WSUD can be applied at a variance of scales and intensity across the city exhibiting a capacity to enhance resilience within both high income and low income areas. Furthermore, as demonstrated, benefits accrued within predominantly high income areas or private developments are far reaching and, if managed correctly, resources are made available for redirection to uplift and enhance sanitation, water supply and WWT services within the areas of the city currently underserved and predominantly occupied by the urban poor. Spatial planning has been discussed as key to the implementation of WSUD, it also plays a fundamental role in the redirection of resources and as such has the capacity to provide benefits for all across the city and widen the spatial influence of enhancing water metabolisms at a city scale.

Effective monitoring and management of the WSUD interventions and infrastructure proposed herein are vital to the success of this system. It is proposed that this management be conducted by a combination of private and public entities essentially to reduce pressures on the already limited capacity of municipal departments. The nature of the River Club development in terms of high public interest and private funding lends itself to promoting public-private collaboration in management. Programmes such as Working for Water and Friends of the Liesbeek can be called upon to aid in the management and monitoring of the Liesbeek River, the companies responsible for the construction of artificial wetlands and boreholes can be used for long-term monitoring. Management and maintenance to maintain open space and individual buildings can be outsourced and funded by occupants' levees.

External consultants comprising a small interdisciplinary team should be appointed to ensure holistic management and overall compliance.

It is clear that the complexities of the water metabolism are considered under the WSUD paradigm which does not regard water resource management as a simple linear system but rather as a complex system with numerous external and internal interactions. This holistic approach thus focusses water resource management beyond water, considering other systems inherent to the urban landscape. Considering these systems enable numerous CoCT developmental objectives to be incorporated within WSUD including concerns for social and environmental justice, human health and well-being and equitable access to opportunities (Revell, 2010). As such utilising WSUD as a mechanism through which to manipulate the urban water metabolism is also a resilience building strategy as the more efficient the metabolism of a city is, the greater its resilience (Revell, 2010).

Conclusion

The case study of the River Club site has demonstrated the ability of spatial planning to promote and implement WSUD within a development plan. In turn, it has also demonstrated the ability of WSUD interventions to inform spatial planning and urban design and facilitate the achievement of multiple objectives such as enhancing 'sense of place', increasing mobility, enhancing legibility, providing quality public open space, in addition to a variety of social, economic and environmental benefits.

The infrastructure associated with WSUD is fundamental to the achievement of these objectives. This infrastructure supports the metabolism of water resources within the development in cyclical fashion predominantly by facilitating maximum use and re-use of water resources thus reducing outputs as waste. It is clear that spatial planning and urban design processes are vital in spatially connecting urban infrastructure and determining 'best fit' infrastructure for a specific purpose. In linking urban infrastructure across a spatial area, spatial planning and urban design reduce redundancies and ambiguities and increase the efficiency and effectiveness of this infrastructure. WSUD and spatial planning complement one another in the promotion of green infrastructure in achieving sustainable development.

The iterative nature of the relationship between spatial planning, urban design and WSUD, provides a means through which to address multiple social, economic and environmental objectives. Sustainable development within the River Club through the incorporation of WSUD within spatial planning achieves beneficial outcomes which extend beyond the site boundaries. The reduced requirements for municipal infrastructure supply and the reduced pressure on existing municipal infrastructure in the area will enable municipal resources, that would have been spent on infrastructure provision and upgrading, to be redirected to areas which currently lack adequate access to safe drinking water and sanitation

services. It is hoped that the example set through incorporating WSUD within spatial planning serves as a catalyst for developments throughout Cape Town to adopt this approach. In this manner, through incremental bottom-up change, spatial planning could be responsible for a systemic transition in Cape Town's approach to urban water management.

Chapter 9: Discussion

Discussion

South Africa's national water policy is regarded as of an international standard regarding national water resources as a collective resource for all citizens. The country, however, faces numerous unique challenges many of which are as a result of a former system of institutionalised racial segregation. Many of these challenges pertain to inequalities in the spatial distribution of water resources access to water related services including potable water, sanitation, and WWT at national, provincial and local levels. Amendments to National legislation and policy reform were required to address these issues in accordance with the democratic governance structures which proceeded Apartheid and promoted a fair and equitable South Africa. The reformed water policy recognised the inequalities and deficiencies in service delivery, issues pertaining to water scarcity and inequitable spatial distribution of water resources throughout South Africa, which indicated the need to harness alternative water resources and higher levels of equality. The NWRS 2 provides a strategic approach to the management of national water resources which promotes equitable access by all to the social, economic and environmental benefits which water resource management provides. The strategy promotes institutional coordination with regard to water resource development and planning within a management approach which reflected the principles of national water policy of equitable access to opportunities and services for all through the equitable spatial distribution of water resources and associated infrastructure. Constant policy review and amendment at a national level indicates the national governments commitment to addressing contemporary issues in a dynamic and complex system. The policy promotes sustainable development as a means through which to facilitate economic growth and development, and address numerous social and environmental factors such as human health and well-being and natural resource conservation in a manner which ensures long-term sustainability.

National water policy dictates the roles and responsibilities of national, provincial and local tiers of government in the management of the countries water resources. In addition, this policy recognises planning as an integral component to water resource management and advocates coordination between spatial planning and water related municipal departments. Cape Town is currently facing a severe water crisis due to a prolonged period of drought attributed to climate change and exacerbated by a rapidly growing urban population. Local municipal departments are under pressure to meet the increasing demands of this growing population in terms of water related services. Many of the city's citizens lack access to adequate water supply, sanitation and WWT services largely due to a lack of capacity and financial resources within local government institutions. These service provision deficits and inequitable distribution of resources perpetuate the spatial inequalities promoted by a divisive and

racially oppressive institutional system, as such the effects of Apartheid are still apparent throughout Cape Town.

The CoCT thus faces unique challenges with regard to the management of urban water resources. Strategies to overcome these challenges have included a focus on infrastructure upgrading and maintenance and have failed to incorporate high levels of capital expenditure on the instillation of infrastructure to meet the growing demands of the urban population. The City is currently faced with service delivery deficits, and failing and over-capacitated infrastructure all of which exacerbated by declining water resource availability. The NWRS, predecessor of the NWRS 2, projected declining water resource availability within the Cape Town local region as early as 2003 attributing this decline to decreasing trends in annual precipitation within the local catchments. The current water crisis, it is argued, could have been avoided if the CoCT had responded appropriately by adjusting water management strategies to reflect these trends and build resilience among local communities against the threat of drought.

The CoCT has directed large investment initiatives toward the development of desalinisation plants however, it has been argued herein, that the city requires an alternative water management approach if it is to adequately address the numerous economic, social and environmental issues and challenges within the city whilst simultaneously compensating for water scarcity by building resilience among local community members. It is argued herein that this new management approach should endeavor to create a water sensitive city through the promotion of sustainable development thus facilitating economic and social development in a manner which protects environmental resources. The achievement of a water sensitive city, it is argued, requires water resource management to recognise the urban water cycle as a system and manage this system in a coordinated and interdisciplinary manner. Management approaches should seek to enhance the metabolism of the water cycle by reducing inputs (water supply) and outputs (waste) through water re-use and recycling, and the promotion of alternative sources of water supply.

WSUD provides a water management approach which focusses on the urban water cycle in its entirety regarding it as a dynamic and interactive system which requires coordinated and interdisciplinary management. WSUD promotes an interdisciplinary approach requiring coordination between spatial planning and water management institutions to enhance water management through a holistic, systems based approach. The principles of WSUD are thus in line with those promoted within national water policy in building resilience among local communities and facilitating sustainable development. Although WSUD is currently recognised within numerous national water policies there has been little success in the application of these principles within local water management approaches.

The major inhibiting factors within Cape Town, in adopting WSUD as an alternative approach to water management, are a lack of financial resources and capacity within municipal departments and the lack of coordination between spatial planning and municipal water institutions. In addition, water management functions within Cape Town are divided among the various municipal departments which exhibit little collaboration in coordinating management approaches. This has resulted in the delineation of the various water management functions, each of which managed in isolation, resulting in failure to regard the urban water cycle as a single system. Based on international precedence and best practice from Australia water policy reform and institutional restructuring will be required in order for Cape Town to be effectively adopted WSUD as an alternative approach to water resource management.

It is argued herein that, given the cost and time limitations currently faced by Cape Town, the City requires an alternative approach to implement WSUD. Spatial planning, through its capacity to facilitate an interdisciplinary approach, public participation, enhance coordination and incorporate the public and private sector within developments at a variance of spatial scales, is promoted as a means through which to implement WSUD in Cape Town. It is argued that spatial planning and the inherent processes of urban design are capable of catalysing a systemic transition in urban water management through a bottom-up approach to implementing WSUD. Furthermore, the incorporation of the principles of WSUD within spatial planning initiatives can be utilised as a holistic water management strategy to target sustainable development and equality in a manner which simultaneously addresses the current water crisis in Cape Town and the numerous social, economic and environmental issues and challenges.

The case study has provided an example of the potential to apply the principles of WSUD within the development of a spatial plan and the potential economic, social and environmental benefits this can produce. The principles of WSUD can be used to promote a wide variety of spatial principles encapsulated within the Cape Town SDF such as densification, increased equality, inclusivity and connectivity. It has indicated the ability to promote WSUD infrastructure within spatial planning and urban design and the capacity of this infrastructure to enhance the local water metabolism in a manner which promotes sustainable water resource use through the recognition of the water cycle as a system and the holistic management of that system. Furthermore, WSUD interventions inform spatial plans in an iterative manner both requiring and facilitating public participation, stakeholder engagement, increased coordination between the public and private sectors, and greater interdisciplinarity.

Chapter 10: Recommendations and Conclusion

Recommendations

WSUD has been recommended as an alternative approach to urban water management in Cape Town to address, and build resilience against, decreasing water security. The research conducted within this dissertation has indicated that local municipal departments contain insufficient resources and capacity to reform policy and reconfigure institutional arrangements in order to address current water management issues and challenges and reflect the coordinated, holistic and systems based approach required by WSUD. It is thus recommended that WSUD be implemented within spatial planning initiatives throughout Cape Town to promote enhanced water management through sustainable development and address numerous national and local development objectives. Spatial policy reform should promote WSUD as a BPP which should be incorporated within spatial plans at a variety of spatial scales throughout the city. This recommendation will allow a bottom-up approach whereby small scale change catalyses a city-wide systemic transition in urban water management.

These recommendations relieve pressures on local municipal departments by addressing pertinent water management needs in a manner which responds to the limitations of these departments by enabling them to address policy amendment and institutional restructuring in a timely manner to formalise a WSUD approach within water management in Cape Town. Furthermore, municipal resources can be redirected to enhancing service delivery to underserved areas and promoting equality with regard to water resource distribution throughout the city.

Proposals to redevelop the TRUP local area have generated much interest and attention by citizens across Cape Town. The area presents a number of opportunities to increase urban densities, enhance connectivity across the city, promote natural systems within the city and address numerous additional objectives in redressing past racially discriminatory transgressions which promoted inequality. An interdisciplinary approach coupled with well-developed public participatory and stakeholder engagement processes are incorporated in the formulation of spatial plans for the area. The River Club is located within TRUP and is central to addressing a number of the above mentioned objectives. As a result it is recommended that the development of this site serve as a catalyst for a systemic transition in urban water management by incorporating the principles of WSUD within the development.

Recommendations for Future Studies

This dissertation has presented numerous opportunities for future studies which could not be adequately addressed within the scope of the research herein conducted given various limitations. Future studies could investigate opportunities for community driven management of local infrastructure, interdisciplinary and public participatory monitoring approaches, efficient and effective

public participatory and stakeholder engagement processes, ways to enhance coordination and cooperation between the private and public sector specifically with regard to water management, and an effective means of incorporating WSUD and its associated principles within spatial policies and aligning these with current spatial objectives. Numerous studies are recommended in endeavors to reform local water policy, institutional arrangements and management practices in a manner which formalises a holistic, systems based and coordinated water management approach within Cape Town. It is also recommended that interdisciplinary studies be conducted to inform local municipal departments in the redirection of financial resources to promote the equitable distribution of water resources and adequate services.

Conclusion

The complex nature of the various components which comprise the urban environment can be thought of as systems. Thus a systems approach should be applied to the management of the various aspects that comprise a city. The urban water cycle is a highly complex system which interacts with a wide variety of environmental, economic and social systems both within and beyond the boundary of a city. Spatial planning has been identified as a mechanism through which to implement WSUD as a systems management approach to promote sustainable development in moving towards a water sensitive city. This requires a systemic transition in current urban water management practices. Given the current lack of capacity within the Cape Town Municipal Departments it has been proposed that spatial planning be utilised as a means to implement WSUD by incorporating the principles thereof within spatial plans and in so doing catalyse systemic change via a bottom-up approach targeting developments at a variance of scales. Furthermore, the national, provincial and local objectives herein discussed can be achieved through incorporating WSUD within spatial planning thereby reducing inequalities by improving access to opportunities and the equitable distribution of resources, in a manner which simultaneously addresses Cape Town's current water crisis.

The objectives of this dissertation to review national and local water policy, the management of water resources in Cape Town, explore WSUD as an alternative approach to urban water management, explore the potential role of spatial planning in implementing WSUD and demonstrating the ability of spatial planning initiatives to incorporate WSUD within spatial plans have been met. This dissertation, as informed by these objectives, has indicated the capacity of WSUD as an alternative water management approach in Cape Town as a means through which to promote sustainable development, build resilience among local communities to the effects of flooding and drought, and address numerous national and local objectives. It has also identified the capacity of spatial planning in implementing WSUD and catalyzing a systemic transition in urban water management in Cape Town. In addition, a

number of recommendations have been generated pertaining to the implementation of this design approach given the specific limitations of the City's municipal departments.

References:

- Adewumi, J.R., Illembade, A.A. & Van Zyl, J.E. 2010. Treated Wastewater Reuse in South Africa: Overview, Potential and Challenges. *Resources, Conservation and Recycling*, 55(2), pp.221-231.
- ESRI. 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.
- Armitage, N., Fisher-Jeffes, L., Carden, K., Winter, K., Naidoo, V., Spiegel, A., Mauck, B. & Coulson, D. 2014. Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines. WRC Report No. TT 588/14
- Atkinson, A. 2004. Promoting Environmentalism, Participation and Sustainable Human Development in cCities of Southeast Asia. in Westendorff, D. Ed. From *Unsustainable to Inclusive Cities*, United Nations Research Institute for Social Development, Geneva.
- Attride-Stirling, J. 2001. Thematic Networks: an Analytic Tool for Qualitative Research. *Qualitative research*, 1(3), pp.385-405.
- Baccini, P. 1997. A City's Metabolism: Towards the Sustainable Development of Urban Systems. *Journal of Urban Technology* 4 (2), 27-39.
- Baccini, P. & Brunner, P.H. 1991. Metabolism of the Anthroposphere. Springer Verlag, Berlin.
- Baguma, D. & Loiskandl, W. 2010. Rainwater Harvesting Technologies and Practices in Rural Uganda: a Case Study. *Mitigation and adaptation strategies for global change*, 15(4), pp.355-369.
- Bahrainy, H. & Bakhtiar, A. 2016. Toward an Integrative Theory of Urban Design. Springer International Publishing.
- Baker, L.A. Ed. 2009. *The Water Environment of Cities*. Springer, US.
- Bakker K. 2003. Archipelagos and Networks: Urbanization and Water Privatization in the South. *The Geographical Journal* 169(4): 328–341.
- Barr, A. & Feigenbaum, E.A. 1981. The Handbook of Artificial Intelligence. vol. 1. Los Altos, CA: VWilliam Kaufman.
- Belcher, T. & Grobler, D. 2016. Aquatic and Water Quality Assessment: Specialist Report for the Two Rivers Urban Park Development Framework, Cape Town. Prepared by Blue Science
- Bohle, H.G. 1994. Metropolitan Food Systems in Developing Countries: the Perspective of Urban Metabolism. *GeoJournal* 34 (3), 245-251.

Brown, R., Beringer, J., Deletic, A., Farrelly, M., Fletcher, T., Grace, M., Hart, B.T., Hatt, B., Keath, N., Lake, S., Lynch, A., Mac Nally, R., Mitchell, G., Mfodwo, K., Morison, P., Stubbs, W., Tapper, N., Van de Meene, S. & Wong, T. 2007. Moving to the Water Sensitive City: Principles for Reform. Monash University Submission to the Review of the Metropolitan Water Sector, Public Submission to the Victorian Competition & Efficiency Commission review of the metropolitan Water Sector.

Brown, R., Keath, N. & Wong, T. 2008. Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States. In *11th international conference on urban drainage* (Vol. 10).

Brown, R.R., Keath, N. & Wong, T.H.F. 2009. Urban Water Management in Cities: Historical, Current and Future Regimes. *Water science and technology*, 59(5), pp.847-855.

Brown, A. & Lloyd-Jones, T. 2002. Spatial Planning, Access and Infrastructure. In *Urban Livelihoods: A People-Centered Approach to Reducing Poverty*, C. Rakodi and T. Lloyd-Jones, Ed. London. Earthscan 188–204.

Brown, J.N. & Peake, B.M. 2006. Sources of Heavy Metals and Polycyclic Aromatic Hydrocarbons in Urban Stormwater Runoff. *Science of the Total Environment*, 359, pp.145-155.

Buhaug, H. & Urdal, H. 2013. An Urbanization Bomb? Population Growth and Social Disorder in Cities. *Global Environmental Change*, 23(1), pp.1-10.

Campbell, S. 1996. Green Cities, Growing Cities, Just Cities?: Urban Planning and the Contradictions of Sustainable Development. *Journal of the American Planning Association*, 62(3), pp.296-312.

Carden, K. & Armitage, N.P. 2013. Assessing Urban Water Sustainability in South Africa - not Just Performance Measurement. *Water SA*, 39(3), pp.00-00.

Chang, T.C. & Huang, S. 2011. Reclaiming the City: Waterfront Development in Singapore. *Urban Studies*, 48(10), pp.2085-2100.

Chirisa, I., Bandaiko, E., Mazhindu, E., Kwangwama, N.A. & Chikowore, G. 2016. Building Resilient Infrastructure in the Face of Climate Change in African cities: Scope, Potentiality and Challenges. *Development Southern Africa*, 33(1), pp.113-127.

City Think Space. 2012. The Two Rivers Urban Park Local Area Sustainable Neighborhood. High Level Development and Urban Design Concept. A project of the Cape Town Central City Regeneration Programme. Department of transport and Public Works.

City of Cape Town (CoCT). 2003a. Integrated Metropolitan Environmental Policy. Environmental Management Department

City of Cape Town (CoCT). 2003b. Two Rivers Urban Park Contextual Framework and Phase 1 Environmental Management Plan. Final Report. City of Cape Town, Cape Town Administration. Environmental Management Branch

City of Cape Town (CoCT). 2008. Integrated Metropolitan Environmental Policy. City of Cape Town C 41/06/08

City of Cape Town (CoCT). 2009a. Management of Urban Stormwater Impacts Policy. City of Cape Town Roads and Stormwater Department. Catchment, Stormwater and River Management Branch. Version 1.1 C 58/05/09

City of Cape Town (CoCT). 2009b. New Catchment, Stormwater and River Management Policies. City of Cape Town: Roads and Stormwater Department. Catchment Stormwater and River Management Branch.

City of Cape Town (CoCT). 2012. Table Bay District Plan: Spatial Development Plan and Environmental Management Framework. Technical Report. City Space Planning Cape Town

City of Cape Town (CoCT). 2013. Updates and Additions to Existing Long-Term Water Conservation and Water Demand Management Strategy. Water and Sanitation Water Demand Management. City of Cape Town

City of Cape Town (CoCT). 2017. Water Services and the Cape Town Urban Water Cycle. City of Cape Town, March 2017.

Coombes, P.J., Argue, J.R. & Kuczera, G. 2000. Figtree Place: a Case Study in Water Sensitive Urban Development (WSUD). *Urban Water*, 1(4), pp.335-343.

Coombes, P.J. and Kuczera, G. 2002. Integrated Urban Water Cycle Management: Moving towards Systems Understanding. In Proceedings of the 2nd National Conference on Water Sensitive Urban Design, Engineers Australia (pp. 2-4).

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J. & Raskin, R.G. 1997. The Value of the World's Ecosystem Services and Natural Capital. *nature*, 387(6630), pp.253-260.

Day, E. & Clark, B. 2012. Development of a Water Quality Index and Related Reporting Tools and Information for Inland and Coastal Waters of the City of Cape Town. Assessment of historical data. Report to the City of Cape Town's CSRM Branch.

Decker, H., Elliott, S., Smith, F.A., Blake, D.R. & Sherwood Rowland, F. 2000. Energy and Material Flow Through the Urban Ecosystem. *Annual Review of Energy and the Environment*, 25, 685-740.

New South Wales Department of Education (DECNSW). 2006. Managing Urban Stormwater: Harvesting and Reuse. Department of Environment and Conservation NSW.

De Groot, R.S., Wilson, M.A. & Boumans, R.M. 2002. A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services. *Ecological economics*, 41(3), pp.393-408.

Desfor, G. & Keil, R. 2004. Nature and the City: Making Environmental Policy in Toronto and Los Angeles. Tucson: University of Arizona Press.

Dillon, P. 2000. Water Reuse in Australia: Current Status, Projections and Research. Proceedings of water recycling Australia, pp.99-104.

Dodman, D. 2009. Blaming Cities for Climate Change? An Analysis of Urban Greenhouse Gas Emissions Inventories. *Environment and Urbanization*, 21(1), pp.185-201.

Department of Water Affairs (DWA). 1994. Water Supply and Sanitation Policy. White Paper. Water – an Indivisible National Asset. Department of Water Affairs and Forestry, Cape Town, South Africa.

Department of Water Affairs (DWA). 1997. White Paper on a National Water Policy for South Africa

Department of Water Affairs (DWA). 2004. National Water Resource Strategy. Department of Water Affairs. First Addition

Department of Water Affairs (DWA). 2013a. National Water Resource Strategy 2: Water for an Equitable and Sustainable Future. Second Edition.

Department of Water Affairs (DWA). 2013b. National Water Policy Review (NWPR). Department of Water Affairs. Notice 888. No. 36798

Dubbeling, M. & Massonneau, E. 2014. Rooftop Agriculture in a Climate Change Perspective. *Urban Agriculture*, p.28.

Dubbeling, M. 2014. Urban Agriculture as a Climate Change and Disaster Risk Reduction Strategy. *Urban Agriculture Magazine*, 27, pp.3-7.

Duvigneaud, P. & Denayeyer-De Smet, S. 1977. L'Ecosystème Urbs, in L'Ecosystème Urbain Bruxellois, in Productivité en Belgique. In: Duvigneaud, P., Kestemont, P. (Eds.), Travaux de la Section Belge du Programme Biologique International, Bruxelles, pp. 581-597.

- Ernstson, H., Leeuw, S.E.V.D., Redman, C.L., Meffert, D.J., Davis, G., Alfsen, C. & Elmqvist, T. 2010. Urban Transitions: on Urban Resilience and Human-Dominated Ecosystems. *AMBIO: A Journal of the Human Environment*, 39(8), pp.531-545.
- Eames, M., Dixon, T., May, T. & Hunt, M. 2013. City Futures: Exploring Urban Retrofit and Sustainable Transitions. *Building Research & Information*, 41(5), pp.504-516.
- Eroksuz, E. & Rahman, A. 2010. Rainwater Tanks in Multi-Unit Buildings: A Case Study for Three Australian Cities. *Resources, Conservation and Recycling*, 54(12), pp.1449-1452.
- Farrelly, M. & Brown, R. 2011. Rethinking Urban Water Management: Experimentation as a Way Forward?. *Global Environmental Change*, 21(2), pp.721-732.
- Ferguson, B.C., Frantzeskaki, N. & Brown, R.R. 2013. A Strategic Program for Transitioning to a Water Sensitive City. *Landscape and Urban Planning*, 117, pp.32-45.
- Findlay, S.J. & Taylor, M.P. 2006. Why Rehabilitate Urban River Systems?. *Area*, 38(3), pp.312-325.
- Fisher-Jeffes, L. & Armitage, N. 2013. Charging for Stormwater in South Africa. *Water SA*. Vol. 39(3), 429-435. ISSN: 1816-7950
- Foster, J., Lowe, A. & Winkelman, S. 2011. The Value of Green Infrastructure for Urban Climate Adaptation. Centre for Clean Air Policy, 750.
- Francis, R.A. 2012. Positioning urban rivers within urban ecology. *Urban ecosystems*, 15(2), pp.285-291.
- Frechtling, J. 2002. An Overview of Quantitative and Qualitative Data Collection Methods. *The 2002 user friendly handbook for project evaluation*.
- Gandy, M. 2004. Rethinking Urban Metabolism: Water, Space and the Modern city. *City* 8 (3), 363-379.
- Gandy, M. 2006. Planning, Anti-Planning, and the Infrastructure Crisis Facing Metropolitan Lagos. In *Cities in Contemporary Africa* (pp. 247-264). Palgrave Macmillan US.
- Getter, K.L. & Rowe, D.B. 2006. The Role of Extensive Green Roofs in Sustainable Development. *HortScience*, 41(5), pp.1276-1285.
- Ghisi, E. & Ferreira, D.F. 2007. Potential for Potable Water Savings by Using Rainwater and Greywater in a Multi-Storey Residential Building in Southern Brazil. *Building and Environment*, 42(7), pp.2512-2522.
- Gill, S.E., Handley, J.F., Ennos, A.R. & Pauleit, S. 2007. Adapting Cities for Climate Change: the Role of the Green Infrastructure. *Built environment*, 33(1), pp.115-133.

- Girardet, H. 1992. *The Gaia Atlas of Cities*. Gaia Books Limited, London.
- Girardet, H. 1999. *Creating Sustainable Cities*. Green Books, Totnes.
- Gleik, P.H. 2003. Water Use. *Annual Review of Environment and Resources*, 28: 275-314.
- Gluckman, L. & Lubbe, R. 2016. Spatial Development Framework: Two Rivers Urban Park. Group Work. University of Cape Town.
- Haden, A. 2017. Scientist Predicts “a Total System Crash in March 2018” for Cape Town’s Water Supply. (Online) Available: <https://www.thesouthafrican.com/scientist-predicts-a-total-system-crash-in-march-2018-for-cape-towns-water-supply/> [Accessed: 25/10/2017]
- Hall, T. 1998. *Urban Geography*, Routledge, London
- Hartley, J. 2004. Case Study Research. Essential guide to qualitative methods in organizational research, pp.323-333.
- Haughton, G. & Hunter, C. 1994. *Sustainable Cities. Regional Policy and Development Series 7*. Jessica Kingsley Publishers, London
- Hellström, D., Jeppsson, U. & Kärrman, E. 2000. A Framework for Systems Analysis of Sustainable Urban Water Management. *Environmental Impact Assessment Review*, 20(3), pp.311-321
- Hermanowicz, S.W. & Asano, T. 1999. Abel Wolman’s the Metabolism of Cities’ Revisited: a Case for Water Recycling. *Water Science & Technology*, 40 (4), 29-36.
- Hiscock, K.M., Rivett, M.O. & Davison, R.M. 2002. Sustainable Groundwater Development. *Geological Society*, London, Special Publications, 193, 1-14.
- Hodson, M. & Marvin, S. 2012. Mediating Low-Carbon Urban Transitions? Forms of Organization, Knowledge and Action. *European Planning Studies*, 20(3), pp.421-439.
- Innes, J.E. & Booher, D.E. 2000. Public Participation in Planning: New Strategies for the 21st century.
- Islam, M.M., Chou, F.F., Kabir, M.R. & Liaw, C.H. 2010. Rainwater: A Potential Alternative Source for Scarce Safe Drinking and Arsenic Contaminated Water in Bangladesh. *Water resources management*, 24(14), pp.3987-4008.
- Jordán, R. & Infante, B. 2012. A Strategic Planning Approach for Developing Eco-Efficient and Socially Inclusive Urban Infrastructure. *Local Environment*, 17(5), pp.533-544.
- Kennedy, C.A. 2007. Applying Industrial Ecology to Design a Sustainable Built Environment: the Toronto Port Lands challenge, In: Engineering Sustainability Conference, Pittsburgh, USA, April 15-18.

- Kennedy, C.A., Cuddihy, J. & Engel Yan, J. 2007. The Changing Metabolism of Cities. *Journal of Industrial Ecology*, 2007 (11), 43-59.
- Kennedy, C., Pincetl, S. & Bunje, P. 2011. The Study of Urban Metabolism and its Applications to Urban Planning and Design. *Environmental pollution*, 159(8), pp.1965-1973.
- Khastagir, A. & Jayasuriya, L.N.N. 2010. Impacts of Using Rainwater Tanks on Stormwater Harvesting and Runoff Quality. *Water Science and Technology*, 62(2), pp.324-329.
- Kunapo, J., Chandra, S. & Peterson, J. 2009. Drainage Network Modelling for Water-Sensitive Urban Design. *Transactions in GIS*, 13(2), pp.167-178.
- Landzein.com. 2017. Kallang River at Bishan-Ang Mo Kio Park. Ramboll Studio Dreiseitl. (Online) Available: <http://www.landezine.com/index.php/2012/06/kallang-river-at-bishan-ang-mo-kio-park-by-atelier-dreiseitl/bishan-park-by-atelier-dreiseitl-landscape-architecture-01/> [Accessed: 03/10/17]
- Lazarova, V., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntau, H., Salgot, M. & Brissaud, F. 2001. Role of Water Reuse for Enhancing Integrated Water Management in Europe and Mediterranean Countries. *Water Science and Technology*, 43(10), pp.25-33.
- Lincoln, Yvonna S. & Egon G. Guba. 1985. *Naturalistic Inquiry*. Vol. 75. Sage.
- Lingard, L. & Kennedy, T.J. 2007. *Qualitative Research in Medical Education*. Association for the Study of Medical Education.
- Louis, G., Scherer, W. & Haimes, Y.Y. 2017. Department of Systems and Information Engineering. University of Virginia. (Online) Available: <http://web.sys.virginia.edu/graduate/concentrations/227-urban-systems.html> [Accessed: 28/09/17]
- Marsalek, J., Cisneros, B.J., Karamouz, M., Malmquist, P.A., Goldenfum, J.A. & Chocat, B. 2008. Urban Water Cycle Processes and Interactions. *Urban Water Series-UNESCO-IHP* (Vol. 2). CRC Press.
- March, J.G., Gual, M. & Orozco, F. 2004. Experiences on Greywater Re-Use for Toilet Flushing in a Hotel (Mallorca Island, Spain). *Desalination*, 164(3), pp.241-247.
- Mattingly, M. 2001. *Spatial Planning for Urban Infrastructure Planning and Investment: A Guide to Training and Practice*. London: Development Planning Unit, University College.
- McFarlane, C. 2010. *Infrastructure, Interruption, and Inequality: Urban life in the global South* (pp. 131-144). New York: Routledge.

Melbourne Water. 2002. Water Sensitive Urban Design: for Large Scale Developers or Small Scale/One Off Projects. Knox City Council

Mentens, J., Raes, D. & Hermy, M. 2006. Green Roofs as a Tool for Solving the Rainwater Runoff Problem in the Urbanized 21st century?. *Landscape and urban planning*, 77(3), pp.217-226.

Mitchell, V.G., Mein, R.G. & McMahon, T.A. 2001. Modelling the Urban Water Cycle. *Environmental Modelling & Software*, 16(7), pp.615-629.

Morrison, G., Fatoki, O.S., Zinn, E. & Jacobsson, D. 2001. Sustainable Development Indicators for Urban Water Systems: A Case Study Evaluation of King William's Town, South Africa, and the Applied Indicators. *Water Sa*, 27(2), pp.219-232.

Myllyla, S. & Kuvaja, K. 2005. Societal Premises for Sustainable Development in Large Southern Cities. *Global Environmental Change*, Vol. 15 No. 3, pp. 224-37.

Naidoo, R. 2017. Capes New Approach to Water Management. (Online) Available:www.infrastructurene.ws [Accessed: 19/08/17]

Neuman, M. 2009. Spatial Planning Leadership by Infrastructure: An American View. *International Planning Studies*, 14 (2): 201–17.

Nevens, F., Frantzeskaki, N., Gorissen, L. & Loorbach, D. 2013. Urban Transition Labs: Co-Creating Transformative Action for Sustainable Cities. *Journal of Cleaner Production*, 50, pp.111-122.

Newcombe, K., Kalma, J. & Aston, A. 1978. The Metabolism of a City: the Case of Hong Kong. *Ambio* 7, 3-15.

Newell, J.P. & Cousins, J.J. 2015. The Boundaries of Urban Metabolism: Towards a Political–Industrial Ecology. *Progress in Human Geography*, 39(6), pp.702-728.

Newman, P.W.G. 1999. Sustainability and Cities: Extending the Metabolism Model. *Landscape and Urban Planning*, 44, 219-226.

Nilsson, K.L. & Rydén, L. 2012. 18. Spatial Planning and Management.

Naess, P. 2001. Urban Planning and Sustainable Development. *European Planning Studies*, 9(4), pp.503-524.

Odum, H.T. 1983. Systems Ecology, an Introduction. *Wiley-Interscience*, New York, NY.

Pacione, M. 2007. Sustainable Urban Development in the UK: Rhetoric or Reality?. *Geography*, Vol. 92 No. 3, pp. 248-65.

Pickett, S. T. A., Cadenasso, M. L. & Grove, J. M. 2004. Resilient Cities: Meaning, Models and Metaphor for Integrating the Ecological, Socio-Economic, and Planning Realms. *Landscape and Urban Planning*, Vol. 69, pp. 369-384

Pidou, M., Memon, F.A., Stephenson, T., Jefferson, B. & Jeffrey, P. 2007. Greywater recycling: Treatment Options and Applications. In *Proceedings of the Institution of Civil Engineers: Engineering Sustainability* (Vol. 160, No. 3, pp. 119-131). ICE Publishing.

Planning Partners. 2016. Overview of the River Club Development Initiative: Presentation to TRUP Stakeholders. April 2016

Pugh, T.A., MacKenzie, A.R., Whyatt, J.D. & Hewitt, C.N. 2012. Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons. *Environmental science & technology*, 46(14), pp.7692-7699.

Pumain, D. 2004. *Scaling Laws and Urban Systems*. University Panthéon-Sorbonne. Paris, France.

Rana, M.M.P. 2009. Sustainable City in the Global North and South: Goal or Principle?. *Management of Environmental Quality: An International Journal*, 20(5), pp.506-521.

Revell, K. 2010. Working with Informality: Increasing Resilience in Cities of the Global South. 46th ISOCARP Congress 2010, Nairobi, Kenya

Rizwan, A.M., Dennis, L.Y. & Chunho, L.I.U. 2008. A Review on the Generation, Determination and Mitigation of Urban Heat Island. *Journal of Environmental Sciences*, 20(1), pp.120-128.

Rohr, H.E. 2012. *Water Sensitive Planning: an Integrated Approach Towards Sustainable Urban Water System Planning in South Africa* (Doctoral dissertation, North-West University).

Roux, A., Munganga, G. & Mali-Bolo, S. 2014. Market Intelligent Report. Greencape

Rudlin, B. & Falk, N. 1999. *Building the 21st Century Home. The sustainable urban neighbourhood*. Architectural Press, Oxford.

Republic of South Africa (RSA). 1997. White Paper on Environmental Management Policy. Department of Environmental Affairs and Tourism.

Republic of South Africa (RSA). 1998. National Environmental Management Act (Act No. 107 of 1998). Department of Water and Environmental Affairs.

Republic of South Africa (RSA). 2011a. National Development Plan – 2030. Our Future – Make it Work. National Planning Commission.

Republic of South Africa (RSA). 2011b. National Climate Change Response White Paper. The Government of the Republic of South Africa, Pretoria, South Africa.

Republic of South Africa (RSA). 2016. Integrated Urban Development Framework: A New Deal for South African Cities and Towns. National Planning Commission.

Sahely, H.R. & Kennedy, C.A. 2007. Integrated Systems Flow Model for Quantifying Environmental and Economic Sustainability Indicators: Case Study of the City of Toronto Urban Water System. *ASCE Journal of Water Resources Planning and Management*, 133 (6), 550-559.

Sandström, U.F. 2002. Green Infrastructure Planning in Urban Sweden. *Planning Practice and Research*, 17, 4, 373-385

Schneider, D.K. 2005. Fundamental Empirical Research Principles. Research Design for Educational Technologists. Version 1.0. University of Geneva

Shutes, R.B.E. 2001. Artificial Wetlands and Water Quality Improvement. *Environment international*, 26(5), pp.441-447.

Sim, C.H., Yusoff, M.K., Shutes, B., Ho, S.C. & Mansor, M. 2008. Nutrient Removal in a Pilot and Full Scale Constructed Wetland, Putrajaya city, Malaysia. *Journal of Environmental Management*, 88(2), pp.307-317.

Schrader, S. & Böning, M. 2006. Soil Formation on Green Roofs and its Contribution to Urban Biodiversity with Emphasis on Collembolans. *Pedobiologia*, 50(4), pp.347-356.

SRK. 2017. Redevelopment of the River Club, Observatory, Cape Town. Revised Draft Scoping Report. SRK Consulting Report No. 478320

Swilling, M. 2010. Sustainability, Poverty and Municipal Services: the Case of Cape Town, South Africa. *Sustainable Development*, 18(4), pp.194-201.

Takano, T., Nakamura, K. & Watanabe, M. 2002. Urban Residential Environments and Senior Citizens' Longevity in Mega-City Areas: the Importance of Walkable Green Space. *Journal of Epidemiology and Community Health*, 56, 12; 913-6.

Takebayashi, H. & Moriyama, M. 2007. Surface Heat Budget on Green Roof and High Reflection Roof for Mitigation of Urban Heat Island. *Building and Environment*, 42(8), pp.2971-2979.

Thériault, J. & Laroche, A.-M. 2009. Evaluation of the Urban Hydrologic Metabolism of the Greater Moncton Region, New Brunswick. *Canadian Water Resources Journal*, 34 (3), 255-268.

- Todes, A. 2012. New Directions in Spatial Planning? Linking Strategic Spatial Planning and Infrastructure Development. *Journal of Planning Education and Research*, 32(4), pp.400-414.
- Tratalos, J., Fuller, R.A., Warren, P.H., Davies, R.G. & Gaston, K.J. 2007. Urban Form, Biodiversity Potential and Ecosystem Services. *Landscape and urban planning*, 83(4), pp.308-317.
- Tress, B. Ed. 2003. *Interdisciplinary and Transdisciplinary Landscape Studies: Potential and Limitations* (pp. 182-191). Delta Program, Alterra Green World Research, Landscape Centre
- Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J. & James, P. 2007. Promoting Ecosystem and Human Health In Urban Areas using Green Infrastructure: A Literature Review. *Landscape and Urban Planning*, 81(3), pp.167-178.
- UN-Habitat. 2009. Planning Sustainable Cities: Global Report on Human Settlements 2009. Nairobi: UN-Habitat.
- Van Buuren, A. & Loorbach, D. 2009. Policy Innovation in Isolation? Conditions for Policy Renewal by Transition Arenas and Pilot Projects. *Public Management Review*, 11(3), pp.375-392.
- Van der Laan, L. 1998. Changing Urban Systems: an Empirical Analysis at Two Spatial Levels. *Regional Studies*, 32(3), pp.235-247.
- Vymazal, J. 2010. Constructed Wetlands for Wastewater Treatment: Five Decades of Experience. *Environmental Science & Technology*, 45(1), pp.61-69.
- Walmsley, A. 2006. Greenways: Multiplying and Diversifying in the 21st Century. *Landscape and Urban Planning*, 76; 252-290.
- Watson, V. 2014. Co-production and Collaboration in Planning–The Difference. *Planning Theory & Practice*, 15(1), pp.62-76.
- Western Cape Government (WCG). 2012. Western Cape Sustainable Water Management Plan – 2012: Part 1: ‘The Water Plan’.
- Western Cape Government (WCG). 2016. Two Rivers Urban Park: Engineering Service Model. Water and Sewerage Infrastructure. In partnership with the City of Cape Town.
- Wheeler, L. 2015. A History of the Friends of the Liesbeek. *Cabo*, 2015(1), pp.17-23.
- Whittemore, C., Nicholson, B. and Nitsche, N. 2004. Chapter 27: Salt River Hydrological Study. *Innovative Modeling of Urban Stormwater Systems*, Monograph, 12, pp.559-588

World Health Organisation (WHO). 1948. Preamble to the Constitution of the World Health Organization as Adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.

Wolch, J.R., Byrne, J. & Newell, J.P. 2014. Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'just green enough'. *Landscape and Urban Planning*, 125, pp.234-244.

Wolman, A. 1965. The Metabolism of Cities. *Scientific American*, 213 (3), 179-190.

Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R. & Shaffer, P. 2007. The DUDS Manual (Vol. 697). London: Ciria.

Wong, T.H. 2006. An Overview of Water Sensitive Urban Design Practices in Australia. *Water Practice and Technology*, 1(1), p.wpt2006018.

Wong, T.H.F. & Brown, R.R. 2009. The Water Sensitive City: Principles for Practice. *Water Science and Technology*, 60(3), pp.673-682.

Wong, T.H. & Eadie, M.L. 2000. Water Sensitive Urban Design: a Paradigm Shift in Urban Design. In 10th World Water Congress: Water, the World's Most Important Resource (p. 1281). International Water Resources Association.

World Commission on Environment and Development (WCED). 1987. Our Common Future, Oxford University Press, Oxford.

Worcester Polytechnic Institute (WPI). 2011. Black River Corridor: Vision for Restoration and Recreational Use. Worcester Polycentric Institute City of Cape Town

Water Research Commission (WRC). 2011. Wastewater Risk Abatement Plan of City of Cape Town. Water Research Commission. WRC Report No. SP 22/11

Zucchetto, J. 1975. Energy, Economic Theory and Mathematical Models for Combining the Systems of Man and Nature. Case Study, the Urban Region of Miami. *Ecological Modelling*, 1, 241-268.

Appendices:

Appendix A: Ethics Consent Form

Application for Approval of Ethics in Research (EIR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town


APPLICATION FORM

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Lloyd Gluckman
Department		Architecture & Planning & Geomatics
Preferred email address of applicant:		Lj.gluckman@gmail.com
If a Student	Your Degree: e.g., MSc, PhD, etc.,	MCRP
	Name of Supervisor (if supervised):	Nancy Odendaal
If this is a research contract, indicate the source of funding/sponsorship		NRF
Project Title		Implementation of Water Sensitive Urban Design as a Transformative Approach to Urban Water Management in South Africa: A case study of the River Club Development

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Lloyd Gluckman		Click here to enter a date.

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Nancy Odendaal		Click here to enter a date. 21/06/17
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduate research (Including Honours).	Click here to enter text.		Click here to enter a date. 21/06/17
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.	G SITHOLE Click here to enter text.		24/7/2017 Click here to enter a date.